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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See page 86, Jan. 12. 5734

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See Full Page Advt. page 48, Jan. 12.

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See half-page Advertisement page 72, Dec. 29.

The Manchester Steam Users' ASSOCIATION.

For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. M. STROMBYER, M.I.C.E.
Founded 1854 by Sir W. FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 5199

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are being carried out, with a view of IMPROVING Present Methods of PUDDLING, i.e., as regards—
TYPE OF FURNACES;
OUT-PUTS;
LABOUR-SAVING APPLIANCES, &c.
The Committee will be pleased to consider suggestions from any parties (Patentees or others) with a view to Investigation, and, if needs be, Practical Demonstration.
Communications, which should briefly outline the suggested improvement, should, in the first place, be addressed to the undersigned, if possible, not later than MONDAY, 29th JANUARY, 1917.
WALTER DIXON, M.I.M.E., M.I.E.E.,
Interim Secretary,
38, BATH STREET, GLASGOW. F 941

A National Need.

BRITISH SCHOOL OF AERONAUTICS.
Aeroplanes and Airships. Construction, Design and Draughtsmanship. Complete Postal Courses. Also preparation for Exams. of Institutions of Civil, Mechanical and Electrical Engineers.—PENNINGTONS, 264, Oxford Road, Manchester. 5387

TENDERS.

TO MAKERS AND USERS OF LOCOMOTIVES.

The MINISTRY OF MUNITIONS are prepared to receive

Offers for New or Good

Second-hand SHUNTING LOCOMOTIVES of various sizes.
The following information must accompany each offer, which must be addressed to Mr. HUBERT BAINES, Deputy Chief Engineer, H.M. Office of Works, Ring Charles Street, Whitehall, London, S.W.: Type, size and weight; maker's name; when built; when and by whom last overhauled; condition; price.
H.M. Office of Works, &c.,
17th January, 1917. F 972

TO MAKERS AND USERS OF STEAM LOCOMOTIVE CRANES.

The MINISTRY OF MUNITIONS are prepared to receive

Offers of Good Second-hand STEAM TRAVELLING CRANES of various sizes.

The following information must accompany each offer, which should be addressed to Mr. HUBERT BAINES, Deputy Chief Engineer, H.M. Office of Works, Storey's Gate, Westminster, London, S.W.—Type; lifting power, whether 2, 3 or 5 tons; radius of maximum lift; maker's name; condition; where seen; price. All for standard gauge only.
H.M. Office of Works, &c.
17th January, 1917. F 973

IN THE MATTER OF THE TRADING WITH THE ENEMY AMENDMENT ACT, 1916.

The PUBLIC TRUSTEE invites

Tenders for the Purchase of

the Whole or any part of 3,579 "A" Shares of £10 each, fully paid, and 1,200 "B" Shares of £10 each, fully paid, in the TUDOR ACCUMULATOR COMPANY, LIMITED, vested in him as Custodian by an Order of the Board of Trade, dated the 2nd October, 1916.
The issued capital of the Company consists of 3,600 "A" Shares of £10 each, fully paid, and 1,200 "B" Shares of £10 each, fully paid.
The purchasers, who must be British-born subjects, will be required to make a sworn Declaration as to nationality and freedom from foreign control on a form to be obtained from the Offices of the Public Trustee.
A report upon the result of the past operations, and the present position of the Company, has been made to the Public Trustee by Messrs. KNOX, CROPPER & COMPANY, Chartered Accountants, of Spencer House, South Place, E.C., and this report, together with copies of the Company's Accounts, can be inspected either at the Offices of the Public Trustee, Kingsway, W.C.; or at those of Messrs. KNOX, CROPPER & COMPANY.
Tenders must be delivered, sealed, to the Public Trustee, Kingsway, W.C., on or before Monday, the 5th February, 1917, at Twelve Noon, marked on the envelope, "Tender, Tudor Shares."
The Public Trustee does not bind himself to accept any Tender, and reserves to himself all rights in connection therewith. F 966
Forms of Tender can be obtained from the PUBLIC TRUSTEE, or from Messrs. KNOX, CROPPER AND COMPANY, Spencer House, South Place, E.C.

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—
HYDRAULIC JACKS.
WOOD HANDLES.
LOCKS, &c.
LAMP GLASSES.
BRASS and IRON or STEEL SCREWS.
Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Hydraulic Jacks," or as the case may be, not later than Eleven o'clock a.m., on Thursday, the 25th January, 1917.
The Directors do not bind themselves to accept the lowest or any Tender.
R. H. WALPOLE,
Company's Offices, Secretary.
48, Copthall Avenue, E.C.
London, 17th January, 1917. F 975

COUNTY BOROUGH OF BRIGHTON.

TO IRONFOUNDERS, METAL MERCHANTS, and OTHERS.

The Corporation of Brighton invite

Offers for the Purchase of

Disused BOILERS and PUMPING MACHINERY, &c.
All further information can be obtained from the Waterworks Engineer, 12, Bond Street, Brighton.
Sealed Tenders must reach me before Ten a.m. on the 19th day of February, 1917.
HUGO TALBOT,
Town Clerk.
Town Hall, Brighton,
16th January, 1917. F 969

BACHELET LEVITATED RAILWAY SYNDICATE, LIMITED.
BRITISH BACHELET FLYING TRAIN SYNDICATE, LIMITED.
BACHELET SHUTTLE & LOOM COMPANY, LIMITED.
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The LIQUIDATOR of the above Companies is open to receive

Tenders for the Sale of the

PATENTS of the above Companies in England and the principal Continental Countries and Japan. The Patents refer to Electro-Magnetic Transporting Apparatus, and include Monsieur Bachelet's inventions for Levitation. A List of the Patents can be inspected by appointment at the Liquidator's Office. The Liquidator does not bind himself to accept the highest or any Tender.
All enquiries to be made of the Liquidator.
W. B. PRAT,
Liquidator.
11, Ironmonger Lane,
London, E.C. F 964

GREAT NORTHERN RAILWAY COMPANY (IRELAND).

The Great Northern Railway Company (Ireland) are prepared to receive

Tenders for:—

Four Pairs of Collapsible GANGWAYS, and Thirty Pairs of Wagon WHEELS and AXLES for 25-ton Goods Brake Vans.
Copies of the Specifications, Drawings and Forms of Tender may be obtained on application to the Secretary, at Amiens Street Terminus, Dublin, on payment of a fee of 10s., which will be refunded on receipt of a *bona fide* Tender and the return of the Drawings.
Tenders, under cover, marked "Tender for ....," should be deliverep to the undersigned not later than Ten a.m. on Monday, the 5th February, 1917.
The Directors no not bind themselves to accept the lowest or any Tender.
T. MORRISON,
Secretary.
Secretary's Office,
Amiens Street Terminus, Dublin,
16th January, 1917. F 948

APPOINTMENTS OPEN.

UNIVERSITY OF LONDON.

NOTICE IS HEREBY GIVEN, that the SENATE will PROCEED to ELECT

External Examiners for the

EXAMINATIONS, other than Medical, above Matriculation, for the year 1917-18, as follows:—
(I.) Geology; (M) Mathematics; (N) Physics; (Q) Electrical Technology.
N.B.—Attention is drawn to the provisions of Statute 134, whereby the Senate is required, if practicable, to appoint at least one Examiner who is not a Teacher of the University.
Particulars of the remuneration and duties can be obtained on application.
Candidates must send in their names to the External Registrar, Geo. F. Goodchild, M.A., B.Sc., with any attestation of their qualifications they may think desirable, on or before Wednesday, January 31st, 1917.
It is particularly desired by the Senate that no application of any kind be made to its individual Members.
If testimonials are submitted, three copies at least of each should be sent. Original testimonials should not be forwarded in any case. If more than one Examinership is applied for, a separate complete application, with copies of testimonials, if any, must be forwarded in respect of each. No special form of application is necessary.
University of London,
South Kensington, S.W. F 945

Wanted, Mill Manager, for

cogging, roughing and finishing mill, experienced in rails, sheet bars, and billets; one experienced in shell bar rolling and gas heating preferable. State age, reference, and salary required.—Address, F 934, Offices of ENGINEERING.

Works Manager (Assistant)

WANTED, for Marine Engineering Works in Clyde District, employing about 700 men. Applicants, who need not necessarily have had marine training, should specify their qualifications for or experience in organising the various departments, stores, &c., along modern manufacturing lines in connection with Premium Bonus System of payment and costing; they should also state their general and technical experience, enclose copies of references, and state salary required.—Address, F 959, Offices of ENGINEERING.

Production Expert Wanted,

in a Government controlled establishment engaged on the manufacture of Motor Transport Vehicles. Experience in the modern methods of production and the designing of Jigs, Tools and Fixtures essential.
Applicants should apply to the nearest EMPLOYMENT EXCHANGE, giving particulars of experience, age, and salary required, mentioning this Journal and No. A 3046.
No man at present on Government work need apply. F 966

Engineer for Running Power

Plant at large Engineering Works in Midlands, one with marine experience preferred. — Apply nearest EMPLOYMENT EXCHANGE, quoting No. A2796. No person already on Government work will be engaged. F 980

Required, for a Large Iron

and Steel Works, a capable ENGINEER, to supervise and control the erection of blast furnace plant. Liberal salary offered to first-class man. Applicants, who should have had experience in expeditious erection of heavy structural work, to state age, experience, and when at liberty. No one already on Government work will be considered.—Address, F 870, Offices of ENGINEERING.

Wanted, Gentlemen of Good

appearance and address, with manufacturing experience, to supervise important Admiralty work at various factories. Sound practical and technical engineering knowledge essential. Suitable applicants will be given commissioned rank and enrolled in the Royal Naval Volunteer Reserve.—Address applications in writing to BOX No. 942, care of Messrs. R. F. WHITE & SON, General Advertising Agents, 33, Fleet Street, London, E.C. F 924

Wanted, Working Engineer,

Six o'clock man, to Take Charge of the running of engines and the working of boilers, economisers, pumps and all auxiliaries belonging to large Power Plant, to direct and supervise engine men, firemen and pipe fitters. Must be a practical mechanic, thoroughly capable, and accustomed to engine running, boiler and economiser operation, maintenance, cleaning and inspection, and must produce references or testimonials certifying experience the applicant has had in similar positions of plant control under actual working conditions. State experience, age, wage, and full particulars. — Address, F 947, Offices of ENGINEERING.

Assistant, over Military Age,

REQUIRED for mechanical department of mine in Portugal. Qualifications: all-round experience, especially on large repairs, railway and mining machinery, good draughtsman, a knowledge of Portuguese or Spanish advisable, also of gas engines and electrical plant. Salary £18 per month first, £19 second, and £20 third year, travelling expenses and furnished quarters. — Send full particulars immediately to Dr. J. I. OWENS, 47, Victoria Street, London, S.W. F 954

SHOEBURYNESS URBAN DISTRICT COUNCIL.

The Council REQUIRE an

Assistant Engineer (over

Military age or otherwise ineligible), used to Gas Engines, Pumps and Well work generally, at their Waterworks, Shoeburyness.
Enquiries as to duties, &c., can be made of the Engineer, Waterworks, Shoeburyness.
Applications, stating age, past experience and wages asked, should be sent to me as soon as possible at the address below.
FREDERIC GREGSON,
Clerk.
Southend-on-Sea,
16th January, 1917. F 933

Estimator and Rate Fixer for

medium and small class repetition work in Munition Factory; automatic and assembly shop experience required. State full details of experience, age, and wages required. No man already on Government work need apply. — Apply, to nearest EMPLOYMENT EXCHANGE, mentioning this Journal and F 873.

Contractors Agent.—Gentle-

MAN REQUIRED at once. Preference given to one who has laid large gas and water mains.—Address, F 937, Offices of ENGINEERING.

Technical Journal. — An

unusual opportunity for an ASSISTANT on the staff of a well-known technical journal, suitable for discharged soldier, or exempt under 35. Must be energetic, well educated, and of agreeable personality. Technical education not necessary.—Reply, with full particulars, giving experience, age and salary desired, &c., &c.—PERMANENT, care of DAWSON'S Advert. Agency, 121, Cannon Street, E.C. F 974

Designer, with Good Mech-

anical Engineering experience, REQUIRED by Admiralty establishment for the duration of the war. No others need apply.—Reply (by letter), stating age, experience, and present salary to BOX No. 919, care of Messrs. R. F. WHITE & SON, Genl. Advng. Agents, 33, Fleet Street, London, E.C. F 950

Assistant Chief Draughtsman

REQUIRED for Steel Works, Sheffield district (controlled establishment), with thorough experience in general engineering, and arrangement and detail work of wire and rolling mill plant preferred. A permanent position, with good remuneration, to reliable man who can take complete charge of drawing office, &c., in the absence of the Chief Engineer. No person on Government work need apply. — Apply, giving full qualifications, age and salary required, to the nearest BOARD OF TRADE EMPLOYMENT EXCHANGE, mentioning this Journal and F 958.

Draughtsmen. — Wanted, in

Glasgow, several First-class DRAUGHTSMEN experienced in the designing of heavy steel works plant, rolling mill machinery, and hydraulic machinery. No one already on Government work need apply.—Reply, stating age, experience, when at liberty and salary required, to nearest EMPLOYMENT EXCHANGE, mentioning A 2796. F 949

Wanted, Draughtsman, well

up in Electric Power Station design, knowledge of building construction and structural steelwork; competent to design and carry out all work in connection with the installation of boilers, machinery, pipework, &c. Must be ineligible for military service. State age, experience, and wages required.—Address, F 955, Offices of ENGINEERING.

Draughtsman, Mechanical,

Wanted, to take leading position in Drawing Office in new Company in Midlands engaged upon urgent War Work. Excellent prospects for a young energetic man. One with some experience in jig and tool design and automobile construction preferred. No man on Government work can be engaged without consent of present employers. Applications in the first instance should be made to the nearest Board of Trade EMPLOYMENT EXCHANGE, mentioning this paper & No. A 2773. F 962

Draughtsmen. Two, Wanted

immediately for Government work. Must be experienced in estimating and designing of large steel-framed buildings, crane gantries, &c. No person already employed on Government work will be engaged.—Apply, stating age, experience, past and present employers, and salary expected, to BOARD OF TRADE EMPLOYMENT EXCHANGE, quoting No. A 2781. F 919

MECHANICAL DRAUGHTSMEN.

Wanted, Two or Three Good

MECHANICAL DRAUGHTSMEN. Must be expert in design of internal combustion engines, preferably as applied to commercial vehicles.—Applications, containing particulars of age, present employers, and salary required, should be forwarded to the DIRECTOR OF MECHANICAL TRANSPORT, Ministry of Munitions of War, 28, Northumberland Avenue, London, W.C. F 963

Draughtsmen, Two First-class

Electrical and Mechanical, REQUIRED by Controlled Firm, London. Those already on Government work need not apply. — Applicants residing within a radius of 10 miles, please write, stating age and full particulars, experience, and salary required, to F 928, Offices of ENGINEERING. Other applicants must apply nearest Board of Trade EMPLOYMENT EXCHANGE, mentioning this Journal and F 928.

Draughtsmen. — Several

Mechanical DRAUGHTSMEN for turbine design and detail WANTED by a controlled firm in the Midlands. Liberal salaries and bonuses to men who can make good. No man on Government work need apply.—Apply, stating salary, and when able to commence, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and No. A 2799. F 933

Draughtsmen Wanted, with

good mechanical or structural experience. Knowledge of electric crane design an advantage. No person already employed on Government work will be engaged.—Apply, stating age, experience, and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and F 885.

Draughtsman Wanted, Ex-

perienced in Modern Steam Engine practice, Rolling Mill Engines and Plant. No one already employed on Government work will be engaged.—Address, with full particulars as to age, experience, and salary required, your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and F 965.

Wanted, at Once, Mechanical

DRAUGHTSMAN, accustomed to constructional steel work (in an East coast County).—Write, stating age, references, and salary required, B. A., care of J. W. VICKERS & Co., Ltd., 6, Nicholas Lane, E.C. F 957

Draughtsman.—Wanted, for

Jigs, Tools and Fixtures for Automobile details in Government controlled establishment. Previous experience essential. State age and salary required.
No man at present on Government work need apply.
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WOOLWORTH BUILDING, NEW YORK.

By FRANK W. SKINNER, New York.

(*Continued from page* 25.)

IN our last issue we described the construction of the piers forming the foundations of the Woolworth Building, and this week we give on page 56, in Figs. 8 and 9, views which will supplement our descriptive particulars. Of these illustrations, Fig. 8 is a view looking down on two adjacent piers, Nos. 41A and 41B (see plan, Fig. 7, on page 2 *ante*), showing in place the girders, 41, by which the piers are connected. The view also shows the bracing of the excavation. Fig. 9 is a view looking down at the bottom of the cofferdam protecting the foundation girders on the pneumatic caisson. The other views, Figs. 10 and 11, on page 56, we shall refer to later on.

THE 23,500-TON STEEL FRAMEWORK, 790 FT. HIGH.

General Features.—As the Woolworth Building is a commercial structure required to provide the most satisfactory accommodation for business and professional offices and virtually to be of the maximum height practicable, the first consideration in the steel design was the determination of the column arrangement and spacing. This was chiefly governed, in the wings of the building, by the maximum and minimum office sizes demanded by the renting agent, and in the tower by the space necessary for the elevator system and by the architectural requirements for the front elevation. It was decided that the most satisfactory system of wind bracing for the tower, where the stresses are the heaviest, was a plate girder portal construction, which was used up to the 28th floor on the Broadway face of the tower. On the opposite side of the tower the portals were replaced by kneebrace struts one storey in height. Above the 28th floor wind stresses are provided for by the depth of the wall girders and by kneebraces connected to the columns. In the wings of the building wind stresses were provided for by single and double plate girders, supplemented, when necessary, by extensions below the bottom flanges of the end sections of their webs, which serve as kneebraces, giving very deep connections to the columns. The use of the girders without kneebraces and a comparatively short projecting plate at the end enabled the outer wall to be made stiff enough without materially interfering with the sizes and locations of windows. In the wind-bracing planes through interior columns ful' triangular bracing was adopted, with struts reaching from floor to floor where they could be concealed in partitions and clear corridors and doorways. Illustrations showing these arrangements of wind bracing will be given later on.

Assumed Loading.—Under the provisions of the New York Building Code the steel framework was designed to resist a lateral wind pressure of 30 lb. per square foot over the entire area of the building. This requirement was considered very excessive by the structural engineer, who maintained that while the wind pressure may be 30 lb. or more over a very limited area, the rest of the surface will be under much lighter pressure or even under negative pressure simultaneously, so that the total pressure need not be estimated at more than 10 lb. per square foot. This assumption is believed to be justified by the fact that there are in New York many tall apartment houses with no wind bracing whatever except what is derived from the exterior walls and from light terra-cotta or plaster board partitions.

Floor Loads.—According to the requirements of the building code, the column live load from the upper floor was assumed at 75 lb. per square foot, and from each succeeding floor was reduced 5 per cent. to a final minimum of 37½ lb. per square foot on the 10th floor and all lower floors. This assumption was also considered extreme by the structural engineer, who stated that the actual live load on office floors does not exceed 10 lb. per square foot, and that it would be safe to extend the 5 per cent. per storey reduction to the minimum 10 lb. per square foot on all of the floors and for the foundation. This provision, with a reduction of the minimum thickness of the exterior walls that are only curtain walls with a steel cage construction, would extend the practicable maximum height of a New York office building, made with the present grade of structural steel, up to about 1,200 ft.

Calculation of Stresses.—Although the wind load was assumed at 30 lb. per square foot, the unit stresses due to it in columns and bracing were permitted to be 50 per cent. in excess of those due to gravity, therefore as a matter of convenience in computation the wind pressure was figured as 20 lb. per square foot, thus giving the same results as applied to determination of cross-sections that would have been the case using 30 lb. and increasing the unit intensity. No allowance was made for wind stresses in interior partitions, but the end walls of the building were assumed to receive one-half of the wind stress delivered to the columns in their planes. The two thirty-storey wings are braced together at every fifth floor, and were assumed to act together in resisting wind pressure by the thickness of the walls and by their regular framing without special bracing.

Tower Bracing Calculations.—Down to the 28th floor the wind stresses are all carried by the braces in the outside walls, the columns being designed for the resulting moment. No bracing was permitted in the centre panels between columns in the east and west rows passing through the tower, so only the two outer panels were braced, between two intermediate lines of columns, thus giving tower bracing in four east and west planes up to the 28th floor. In the north and south planes bracing was different, the plate girder portals extending up to the 28th floor on the Broadway front, with the braces and other connections above that elevation.

On the opposite or west face of the tower three panels were braced up to the 28th floor, except for the omission of the centre floor panel below the fourth floor. Below the fourth floor the stresses were assumed to be carried to the foundations through two independent towers formed by the bracing in the side panels. There was no interior bracing in north and south planes, because it was assumed that the solid floors and the flat diagonal bracing on the top floor beams distributed the stresses between the exterior walls. Below the 28th floor there were thus provided four double panel systems of east and west bracing, in which each panel was considered as an independent tower with two columns, and two systems of three panels each in the north and south direction. In figuring the stresses it was assumed that the direct loads in the columns caused by the turning moment were directly proportional to the distance from the neutral axis of the group, and, with the horizontal wind loads, were carried equally by each column of the group.

The total wind load at the fifth floor is 533,000 lb. for the group of columns 11–21, 31–41 (see plan, Fig. 7, on page 2 *ante*, in which the columns are numbered), in the Broadway front of the tower. For the three panels in this group the overturning movement is $533{,}000 \times 14 = 7{,}462{,}000$ lb. The neutral axis being the centre of the middle panel, the stresses in columns 21 and 31 are 144, and in columns 11 and 41 are $40{\cdot}8a$ when a is the stress at unit distance from the neutral axis. The resisting moment of these columns is $2(14^2a + 40.8^2a) = 7{,}460{,}000$ lb.

As the above stresses are due to the wind on a single storey, the total wind load on the columns is the sum of the loads of all the stories above, each acting as an independent frame. The bending moments of the portal braces are found by assuming the shear to act equally on each column, passing vertical sections through bracing and finding the resultant moment of the increment of the column load and the shears acting to the left of the section. Thus at column 11 the moment M is $133{,}000 \times 14 = 1{,}860{,}000$ ft.-lb. At the left of column 21 the moment is $133{,}000 \times 14 - 81{,}600 \times 26{\cdot}8 = -333{,}000$ ft.-lb. At the right of column 21, $M = 2(133{,}000 \times 14) - 81{,}600 \times 26{\cdot}8 = +1{,}530{,}000$. At the left of column 31, $M = 2(133{,}000 \times 14) - 86{,}000 \times 54{\cdot}8 - 28{,}000 \times 28 = -1{,}530{,}000$. At the right of column 31, $M = 3(133{,}000 \times 14) - 86{,}000 \times 54{\cdot}8 - 28{,}000 \times 28 = +330{,}000$, and at column 41, $M = 3(133{,}000 \times 14) - 86{,}000 \times 81{\cdot}6 - 28{,}000 \times 54{\cdot}8 - 28{,}000 \times 26{\cdot}8 = -1{,}860{,}000$.

The above analysis of computation was given by F. F. Holtsman, in an article published in the *Engineering Record*, page 22, volume lxviii. In the wings of the building columns were proportioned to resist the moments caused by the shear applied at the points of contraflexure, which were assumed to be at the centres of their unsupported lengths. In all cases the direct compression in each column exceeded its maximum tension, so that no columns were spliced either for bending or for direct tension. The maximum unit stresses in the columns are about 14,000 lb. per square inch, and the maximum column load is 9,500,000 lb. The lateral dimensions of the columns were limited to about 3 ft. by 4 ft., and as some of them have cross-sections of 700 sq. in., their construction with webs of built-up plates necessitated a thickness of metal of over 5 in., which is so near the limit for satisfactory riveting that the structural engineer does not consider it practicable to design a building more than 800 ft. high under similar conditions unless the columns are spaced closer together, increasing the cost and seriously interfering with the architectural and commercial requirements of the building.

STEEL SPECIFICATIONS.

The quality and fabrication of the steelwork were governed by specifications corresponding to advanced practice for first-class heavy bridge work. Among the principal clauses were the following:—

Quality of Steel.—All structural steel must be of open-hearth steel of American manufacture. It must have ultimate strength in tension of from 60,000 to 70,000 lb. per square inch, an elastic limit of at least one-half ultimate strength and an elongation of at least 22 per cent. in 8 in. Chemical analysis shall show not more than 0·6 per cent. of phosphorus. Test pieces must be capable of being bent cold through 180 deg. to a diameter equal to the thickness of the test pieces without showing sign of fracture on the outside of the bent portion.

Rivet Steel.—All rivets, bolts and tie-rods shall be made of open-hearth steel, having an ultimate tensile strength of from 48,000 to 54,000 lb. per square inch, an elastic limit of at least one-half the ultimate strength, and an elongation of at least 24 per cent. in 8 in. Test pieces must be capable of being bent cold on themselves through 180 deg. and flattened without sign of fracture on outside of bend.

Shop Work.—Punching and drilling must be so accurately done as to bring holes exactly opposite one another when pieces are assembled. Small irregularities may be removed by reaming, but larger ones will be cause for rejection of the member. Holes in material up to ¾-in. thickness may be punched full size. Holes in material from $\frac{7}{16}$ in. to $\frac{13}{16}$ in. thick to be punched, and material $\frac{14}{16}$ in. thick to be drilled from the solid.

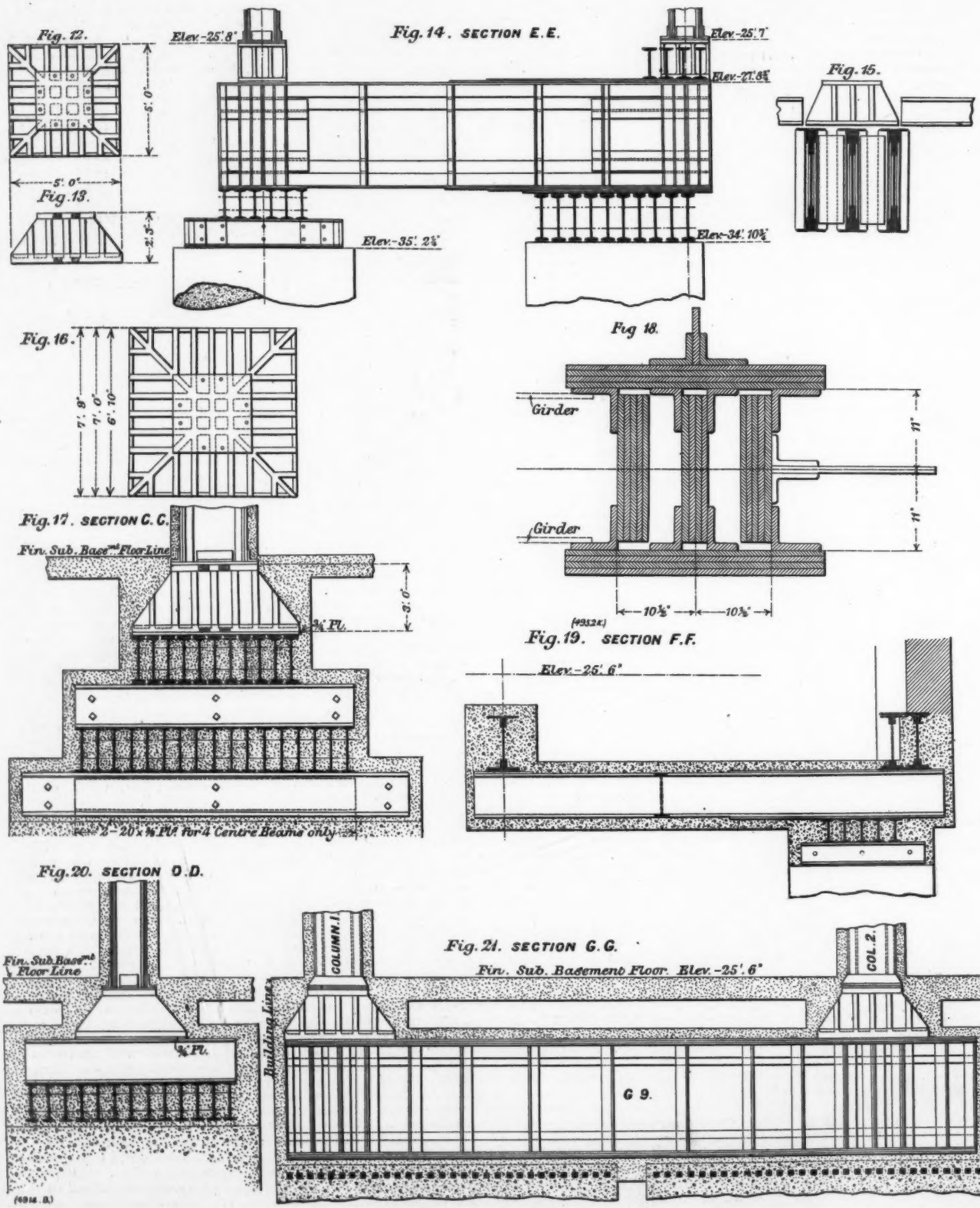
Riveting.—All connections, both in the shop and field, shall be made with rivets, except as specified under turned bolts. Rivets must be driven by machine, both in the shop and in the field, except that in special cases permission will be given for the use of hand-driven rivets.

Turned Bolts.—In places where it is deemed impracticable to drive good rivets, turned bolts shall be used in making the field connections.

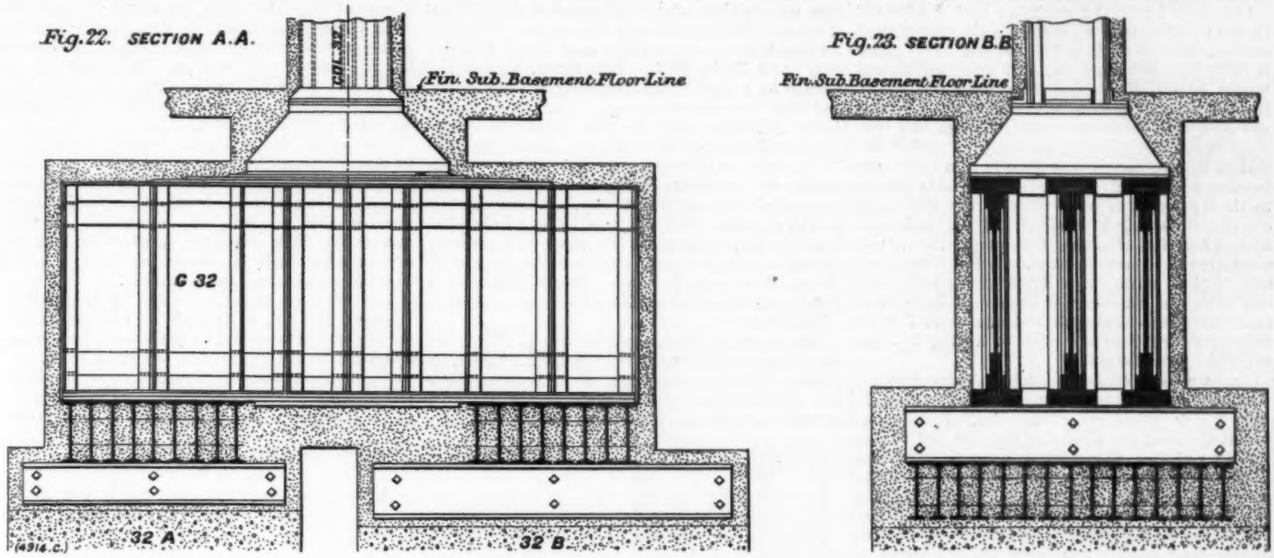
Painting.—All steel and iron is to be carefully cleaned from dirt, rust and loose scale, and after being inspected it shall be painted with one coat of red paint in the shop before being shipped, faced surfaces included. The steel must be perfectly dry and clean when painted. The utmost care must be exercised to have a perfect job. An inspector will be detailed to watch this work. Surfaces in contact must each have a heavy coat of paint before being assembled, and surfaces inaccessible after assembling, like the inside of box columns, must have two coats of paint before being assembled. Time must be allowed for each coat to dry thoroughly before the next coat is applied. If the steel, when it arrives at the building, shows that the paint has been applied over dirt or scale, all of the paint to be removed and the material repainted. Parts from which the paint has been scraped off or abraded, and parts bearing erection marks, to be touched up before painting with the succeeding coat. Field rivets to be painted a first coat before the general second coat is applied. After the steel is erected it is to be given one additional coat of red lead paint of a shade different from that used

THE WOOLWORTH BUILDING, NEW YORK; FOUNDATION GIRDERS.

(For Description, see Page 47.)



THE WOOLWORTH BUILDING, NEW YORK; FOUNDATION GIRDERS.



in the shop, and two coats of R.I.W. paint, manufactured by Toch Bros., of New York, on all steel in ground-floor framing and all below, but, above this level, to have one coat of R.I.W., making three coats in all above ground floor and four below. The second coat is to be of a shade different from the first. The third and fourth coats on steel below the street level to be No. 100 R.I.W. and above this level of No. 112 R.I.W. The R.I.W. paint to be received in barrels, be kept tightly covered after opening and be used without thinning or mixture of any other materials, except by permission of the architect. The paint to be applied by hand on dry, clean surfaces, with large round brushes, and to be well rubbed out. No paint to be applied in the rain.

The red paint to be composed (by actual weight and measurement) of the following materials in the following proportions:—30 lb. best quality approved brand, 99 per cent. pure, finely ground red lead, the brand to be selected by the architect; 1 gal. pure linseed oil, averaging one-half each boiled and raw, as required, using a larger proportion of raw oil in warm weather and of boiled oil in cold weather; ½ pint good turpentine drier. And if the paint sags after applying, add ½ pint varnish, worth 1.50 dols. per gallon. No varnish to be used unless needed to hold the surface. Add lampblack as needed for the second coat.

The above to be thoroughly well mixed in a revolving churn in small quantities, freshly, as required for use, to be used in small pots and be kept stirred in the pot, and be applied by hand evenly over all surfaces, with round stiff brushes, not less than 2-in. diameter, and be well rubbed out. The second coat on large surfaces may be applied by pneumatic spray.

Drawings.—The detail drawings for the steel work comprised many hundreds, some of them of large size. They were made in the offices of the structural engineer, where a large force of draughtsmen and engineers were employed on them from January 22 to April 29, 1911. These drawings were made, as far as possible, of uniform sizes and conformed in arrangement and other particulars to the standards adopted in the structural shop where the work was fabricated. They were fully detailed, giving all materials, dimensions, spacings, clearances and shop notes, so that they were suitable for shop drawings for the fabrication of the members without necessitating the preparation of new drawings to conform to shop practice, which is so often required for designs submitted by architects or engineers without special facilities for structural steel detailing.

Details of Columns.—Some of the columns in the highest stories having minimum sections are made of pairs of rolled channels or of built channels latticed. All other have closed rectangular cross-sections made up of two built channels, one or more thicknesses of cover plate. In the lower stories the very heavy sections have increased areas, secured by the addition of a centre web parallel to the web of the outer built-up channels. A sample section of a column of this class is given in Fig. 18 on page 48. The columns receiving the portal braces in the four stories of the tower have full-length vertical ribs projecting from the faces of the cover plates to receive the field-riveted connections to the webs of the portal girders, which extend the full depth of the storey. They also have one thickness of the cover plate on each face projecting beyond one of the flanges of the built-up channel to provide similar connections for the double portal girders in the opposite planes. We shall illustrate examples of this construction later on.

The maximum column load of 9,500,000 lb., made up of dead and live stress combined, together with the weight of the column itself, required altogether a cross-sectional area of 700.7 sq. in. of gross. This was made up of two plates 43½ by ⅞ in., six plates 40 by ⅞ in., four plates 21 by ⅞ in., ten plates 21 by ¾ in., one plate 7 by 1 in., eight angles 6 by 4 by ⅞ in., eight angles 8 by 6 by ⅞ in., and two angles 5 by 4 by ½ in.

This column, including details, weighs 2,500 lb. per linear foot and is heavier than any column previously used in building construction. The centre web has four thicknesses of plate, two pairs of flange angles, and two pairs of reinforcement angles, which were riveted up complete separately, as were the two sets of cover plates, while the two sets of cover plates were riveted to it, making an H-shape cross-section. The two outer webs, which are built channels, each having five thicknesses of web plate, two flange angles and two centre reinforcement angles, were riveted up separately and forced between the flanges of the H-section and rested there without particular difficulty, although this type of construction is usually objected to at the bridge shop on account of possible difficulty in entering the outside webs between the cover plates.

All columns are seated on cast-steel pedestals, from 18 to 36 in. high, with longitudinal, transverse and diagonal vertical webs. Examples of these pedestals are illustrated in Figs. 12, 13, 16 and 17, on page 48. In order to set close to the building line, some of them are supported on the overhanging short arms of cantilever girders. Others were seated on distributing girders, to transmit their loads to two piers, examples of this arrangement being shown in Figs. 14 and 21, on page 48, and Fig. 22, on the present page. When not seated on the top flanges of the girders the pedestals are seated directly on the upper tiers of grillage beams, across which their bases extend, so as to distribute the load equally among all of the beams in that set. The grillages are made with from two to four tiers of I-beams bolted together with cast-iron separators and enclosed in a solid mass of dense rich concrete filling the interstices between webs and extending a minimum distance of 6 in. beyond the metal in every direction. A good example of this grillage is illustrated in Fig. 17, on page 48, this view being a section at C C, in Fig. 7, on page 2 *ante*. This grillage carries column No. 11.

Sub-structure Girders.—The location of some of the columns eccentric with or entirely outside of some of the piers necessitated, as stated above, the use of heavy foundation girders interposed between the column pedestals and the pier grillages, to transfer the column load laterally and provide for the application of loads on the centres of piers. This necessitated the use of eight distributing girders, each connecting two piers, and all but one of them being required for the tower columns. There were, besides, six cantilever girders required to support the columns in the rear of the building, opposite the Broadway front, which were set very close to the building line.

Girder 41, which carries the load to piers 41A and 41B, is typical of the distributing girders. It is 23 ft. long, 8 ft. deep and 6 ft. 9 in. over all, and weighs about 130,000 lb. It has three webs, each 4 in. thick, built up of several plates stitch-riveted together. After the flange angles were riveted to the web plates, the projecting edges of the latter were removed by planing them, and the surfaces of the flange angles were planed away about $\frac{1}{16}$ in. beyond the original flange surface to provide a perfectly true and accurate bearing to receive the flange cover plate. The girder webs are connected by six sets of vertical transverse diaphragm plates shop-riveted to the flanges of vertical web stiffener angles. Bearing plates, ¾ in. thick and 82 in. square, are countersunk riveted to the top and bottom flanges of the girder to receive the column pedestals and to rest on the pier grillages. The bearings of this girder on the piers are 2 ft. 7 in. apart on centres, and the girder carries a centre column load of 9,600,000 lb. The ends of the vertical web-stiffened angles were accurately milled to bear against the horizontal legs of the flange angles, and instead of being crimped, as in English practice, to fit round the vertical legs of the flange angles, they were offset from the web plate by the solid filler pieces of the same thickness as the flange angles.

Another example of a triple distributing girder, namely, girder G 2, is illustrated in Figs. 14 and 15, on page 48. This girder supports columns Nos. 49 and 50 and connects a circular to a rectangular

pier. The view Fig. 14 is a section taken at E–E, marked on Fig. 7, on page 2 *ante*.

Cantilever girder G 2 received a load of 3,260,000 lb. from wall column 50, applied at the extremity of the long arm, 16 ft. from the fulcrum. This girder is 22 ft. long, 5 ft. deep and 5 ft. wide over all, and weighs 50,000 lb. It has three webs, the spaces between which, like those of the distributing girders, are filled with solid concrete. Although this concrete filling was intended primarily to protect the girders from corrosion, it doubled in many cases the bending strength of the girders, and adds greatly to their carrying capacity through the additional compressive strength provided and the resistance against buckling, although these properties are not considered in the computation. Some of the cantilever girders which carry lighter loads have only two webs, and the one that supports column 61 is made with two full-length and one short I-beam with reinforced flanges instead of having built-up web and riveted flanges.

Fig. 19, on page 48, shows a different arrangement, namely, that indicated at section F–F, on Fig. 7, page 2 *ante*, while other examples, each having special features, are shown in Figs. 20 and 21, on page 48, and Figs. 22 and 23, on page 49. Of these views Fig. 20 shows the support of column No. 51, while Fig. 21 shows girder G 9, which supports columns Nos. 1 and 2, and connects two of the narrow rectangular piers to which reference has already been made. The view Fig. 21 shows a section on the line G–G marked in Fig. 7, on page 2 *ante*. Finally, Figs. 22 and 23, on page 50, show a heavy triple girder, G 32, which connects piers Nos. 32A and 32B and supports column No. 32. The section lines A–A and B–B, corresponding to the two views, will be found marked in Fig. 7, on page 2 *ante*. The view Fig. 10, on page 56, shows one of the heavy distributing girders being got into position for lowering.

(*To be continued.*)

GREAT WESTERN RAILWAY DEVELOPMENTS IN BIRMINGHAM.

MOOR-STREET PASSENGER AND GOODS STATIONS.

IN ENGINEERING of January 2, 1914, and subsequent issues, we gave an account of the various stages by which the Great Western Railway Company's route to Birmingham has been shortened and improved in recent years. We gave also a detailed description of the new passenger station at Snow-hill, and showed that, large as was the accommodation there, the Great Western Company had thought well to supplement it, so far as suburban traffic is concerned, by providing a subsidiary terminal station at Moor-street.

The location of Moor-street station is shown in Fig. 1 annexed. It is in an exceedingly busy part of the city and adjoins several markets—features which led to the extension of the original scheme by provision being made for goods traffic.

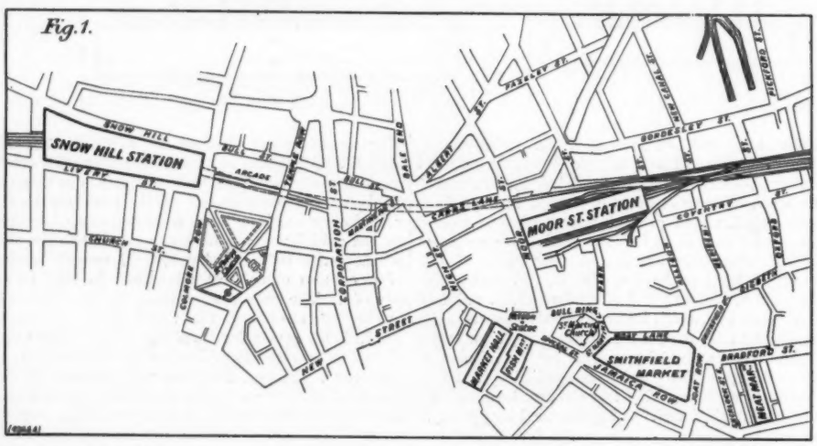
As is not infrequently the case, a competitive scheme was responsible for some portion of the Moor-street development. In 1894 a Bill was deposited for the construction of a railway from Stratford-on-Avon to Birmingham, with connections to the Great Western Company's Alcester and Bearley branch and the East and West Junction Railway. This line was known as the Birmingham, North Warwickshire and Stratford-on-Avon Railway, and was promoted by a number of influential landowners, with the object of opening up the country between Birmingham and Stratford-on-Avon for residential purposes and to form an alternative route from Birmingham to London *via* the East and West Junction and Great Central Railways, in competition with the Great Western. Moor-street was selected for the Birmingham terminus of this new line. The Birmingham and North Warwickshire Company's powers, however, were transferred to the Great Western Company under the Great Western Act of 1900, when it was decided to make Moor-street the terminus of a suburban passenger service. Subsequently an opportunity presented itself of obtaining additional premises, thereby enabling a commodious goods depôt to be added.

Moor-street station is connected to the main line of railway from London to Birmingham and Birkenhead by a short spur line of about 26 chains. This line crosses three streets—Meriden-street, Allison-street and Park-street—and for the greater part of its length is on a brick viaduct, of which the spans vary from 33 to 46 ft. Park-street, however, is crossed by a steel bridge consisting of plate girders and brick jack arches.

The Passenger Station.—The passenger station accommodation consists of an island platform 700 ft. long, with booking and other offices, waiting rooms, &c., abutting Moor-street. In due course another platform of 600 ft. can be added to meet growth of traffic. For 405 ft. of its length the platform (see Fig. 2, Plate VI) is covered with umbrella roofing carried on built-up steel columns supplied by Messrs. E. C. and J. Keay. The glazing used is Hope's patent, and the galvanised sheeting Taylor's "Universal."

The booking office, waiting rooms, &c., are commodious structures of red brick, with blue brick plinths and stone dressings, while between them and the entrance to the platform is what may be termed a concourse. This is covered by five bays of ridge-and-furrow roofing, on which is Rendle's "Invincible" glazing.

Fig. 1.



The contract for the station buildings was carried out by Mr. T. Rowbotham, of Birmingham, and the steelwork was sub-let by him to Messrs. Hill and Smith, of Brierley Hill.

An outstanding feature of the passenger accommodation is two electrically-driven traversing tables, one on either side of the island platform. These take the place of cross-over roads, thereby saving space, and enable engines to be promptly run round their trains and, at the same time, utilise the whole length of the platform. Each traversing table (Fig. 3. Plate VI) is 60 ft. long and 32 ft. 10 in. wide, carries three tracks, and is capable of travelling with a load of 170 tons at 10 ft. per minute. It is provided with 36 travelling wheels, 2 ft. diameter, which run on nine rails fixed at right-angles to the track rails, or four wheels to each rail. There are nine under-carriages, each composed of two rolled steel joists, on the top of which are secured the rail-bearing girders. Chequered steel plates cover the tops of the traversers and project under the nosing of the platform so as to prevent anyone falling into the pit. The edges are finished off with a skirting of angle-iron. The motive power is a three-phase motor with wound rotor of 18 brake horse-power, running at 710 r.p.m. The motor and driving machinery for each table are carried on the traverser, approximately in the centre, under the chequered steel plates, one of which forms a door, for purposes of inspection and access, directly over the machinery. The motor is coupled direct to a steel worm, which gears into a worm-wheel with a cast-iron centre and phosphor-bronze rim, the complete worm-gear being contained in a cast-iron box with oil well. An electric brake is fitted to the worm-shaft, designed to give equal braking force in both directions and to free the shaft from any bending action due to pull of the brake band.

The motive power is transmitted from the motor to the steel worm and thence to the worm-wheel, which is keyed to a countershaft extending in both directions from the centre line of the traverser, the ends of the countershaft, in turn, gearing into two cast-steel wheels on each driving shaft. To prevent the traversers over-running, limit switches are provided. Beneath the passenger platform is a recess into which the tables "pocket" up to nearly the middle of the platform.

The handles controlling the traversers are placed between the stop blocks, and safe working is ensured by an ingenious interlocking arrangement between them and the signal-box frame, whereby the signalman is able to lock or unlock the traverser mechanism, while the lever by which he does this is interlocked with the semaphore signals applying to trains approaching the traversers.

The traversers were constructed by Messrs. S. H. Heywood and Co., of Reddish, near Stockport, and the motors were supplied by the Lancashire Dynamo and Motor Company, 28, Victoria-street, S.W.

The Goods Station.—Although Moor-street station was designed originally for passenger traffic only, the goods business is now a dominating factor there. Prior to its construction, the Great Western Company's goods traffic in Birmingham was mainly dealt with at their Hockley depôt, situated some distance from the commercial centre of the city and involving substantial expense for cartage over steep gradients. In view of this, advantage was promptly taken of an opportunity to acquire certain property belonging to the corporation, lying between Moor-street and Park-street, thereby enabling provision to be made for a goods station. Parliamentary powers were obtained in 1910 and plans prepared for a depôt between Moor-street and Allison-street.

The ground here falls rapidly, the street levels on the site of the depôt being: Moor-street, 391; Park-street, 366; and Allison-street, 354. This configuration lent itself to a two-level depôt, comprising a high level, with access to Moor-street, and under it two sheds at slightly different levels, divided by Park-street—shed A being to the north-west and shed B to the south-east of that road. Shed A lies between Moor-street and Park-street, with access from the latter. Shed B is between Park-street and Allison-street, with access from Allison-street. Adjoining that street there is also stabling accommodation for 67 horses, with provender and straw stores, loose boxes and a shoeing forge.

Fig. 10, Plate VII, is a plan of the passenger station and high-level goods depôt, while Fig. 11 shows the relative positions of sheds A and B and Fig. 12 is a plan of shed B to a larger scale. The first contract in respect of the goods accommodation was simply for the paving and permanent way under the arches between Park-street and Allison-street, on which the passenger station is built. This was let in 1909, and in 1910 a contract was let for covering in the area between Park-street and Allison-street in lateral extension of the viaduct arches carrying the railway. This covering, which forms the floor of the high-level goods yard, is of ferro-concrete, the supporting columns being of the same material. The system

adopted is the Hennebique construction, to designs by Messrs. L. G. Mouchel and Partners, of Westminster. The area of the covering is 4,761 sq. yards. It rests on ferro-concrete columns in the centre and on one longitudinal side. The other sides are carried by brick walls (upon which the secondary beams are supported by means of 2 ft. by 3 ft. ferro-concrete templates) and brick piers carrying the main beams by means of 4 ft. 6 in. ferro-concrete templates.

The foundation slabs under the ferro-concrete columns rest on sandstone and bring a load of 6 tons per square foot on it. For example, taking a central ferro-concrete column of 2 ft. 6 in. by 3 ft. section, the slab under it is 11 ft. by 11 ft. square, bringing a load of 726 tons on the ground.

The decking is formed by a general ferro-concrete slab 6 in. thick, this slab resting on secondary beams 12 in. by 3 ft. 6 in. at centre, 38 ft. span (Figs. 4 to 7, Plate VI). The main beams between the ferro-concrete columns are arched, with a depth at centre of 8 ft. and 10 ft. at springing. The decking is covered with 2 ft. 7 in. of filling and provided with air spaces 15 ft. long and 3 ft. wide for ventilation and light for the lower level. The ferro-concrete decking has to carry a number of stanchions supporting a steel roof over the goods shed. The loads brought by these stanchions on the decking vary from 10 tons to 15 tons each.

A lift opening, 16 ft. 8 in. by 30 ft., is provided, with the necessary ferro-concrete trimmings; also a capstan-box, 7 ft. 3 in. by 4 ft. by 3 ft. deep. The general details of the ferro-concrete construction were as shown in Figs. 4 to 9, Plate VI, the floor being constructed for a super-load of 3 cwt. per square foot.

A small ferro-concrete retaining wall is also provided for this work on a length of 32 ft. between the brick wall and the first ferro-concrete column. This wall has an area of 13 sq. yards and is made with a 7-in. curtain and 10 by 24 in. counterforts with a foundation slab 4 ft. wide and 8 in. thick (see Figs. 8 and 9, Plate VI).

The extension over the remaining land, next to Shut-lane and lying between the passenger station and the main lines, provides an area of 535 sq. yards. The structure is designed for a super-load of 4 cwt. per square foot. The decking is formed by a general ferro-concrete slab 6 in. thick, resting on secondary beams, 18 in. by 5 ft., of a span varying between 52 and 63 ft. The secondary beams are carried by the longitudinal main beams at the sides, 10 ft. deep, with a maximum span of 50 ft. Fig. 14, Plate VIII, shows the extensive nature of the ferro-concrete construction, and Fig. 13 is a general view of shed B, complete with platforms, &c.

Having covered over the site of shed B, the building of the walls of shed A was commenced, followed by the erection in steelwork of the bridge over Park-street, the construction of the high-level goods shed, and the ferro-concrete covering over shed A between Park-street and Moor-street. The last-named covering provided an area of 6,475 sq. yards, and the general particulars of construction were similar to those for shed B.

The high-level goods shed (see Figs. 15 and 16, Plate IX) is 420 ft. in length and 78 ft. 2 in. in width, narrowing to 70 ft. 3½ in., in two spans, one being 31 ft. 8½ in., and the other 46 ft. 5½ in., the latter being reduced at one end to 38 ft. 6¾ in. The columns are 28 ft. 10 in. centres, with the exception of those over Park-street, which are 46-ft. centres, thus avoiding columns on the bridge. The structure generally is of steel. A portion of each roof is glazed with Hope's patent glazing, which, with windows in the sides of the building, admits ample light. The unglazed portions of the roofs are covered with Taylor's patent sheeting, as also are the sides and gable ends, the sheeting being brought down at the sides to 8 ft. above rail level.

The height of the shed from rail level to the underside of the bottom member of the roof principals is 27 ft. 6 in. The smaller span of the shed has crane girders on each side, fixed to brackets from the columns, to carry an under-hung electrical traversing crane, which travels the length of the shed, over the platform, to within 15 ft. of each end. This crane will be described in detail hereafter.

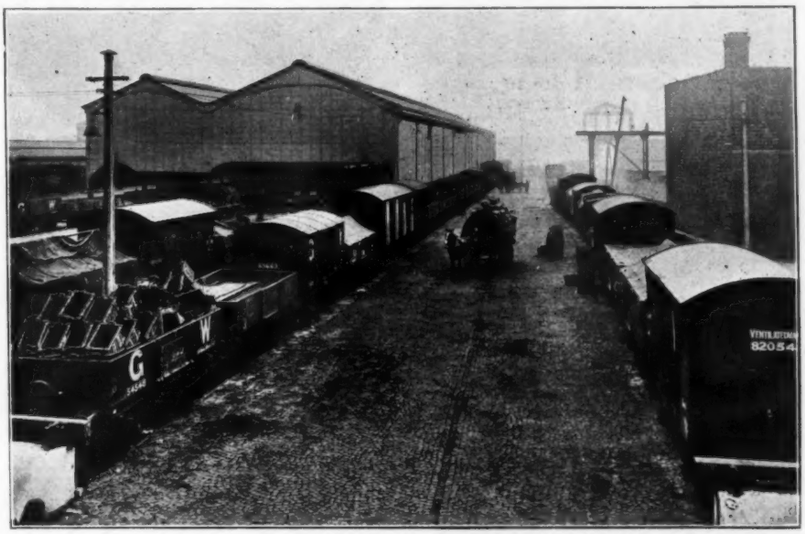


FIG. 17. HIGH-LEVEL GOODS YARD.

The goods platform extends the whole length of the shed and is 20 ft. wide. On one side is a siding and on the other a cart road 35 ft. wide, bordering which is another siding. The road and yard are paved with Durax setts on 9-in. cement concrete and ½-in. tarred chippings, the joints being run with pitch and grouted with Portland cement. The high-level goods yard is shown in Fig. 17 above.

The steelwork contractors were Messrs. E. C. and J. Keay, and the general contractor was Mr. Thomas Rowbotham, of Birmingham. The whole of the civil engineering work was designed and carried out under the supervision of Mr. Walter Y. Armstrong, who until recently was New Works Engineer to the Great Western Railway Company.

(To be continued.)

IRON-ORE DEPOSITS IN AFRICA.—Iron-ore deposits in the German colonies of West Africa are reported as large by a French authority, says the *Iron Age*. In Togoland the iron ore is hematite, containing 89.51 per cent. of iron oxide, 9.47 per cent. of infusorial earth, 0.24 per cent. of alumina, 0.16 per cent. of manganese oxide, and the phosphorus content is equivalent to 0.30 per cent. of phosphoric acid. The deposits probably represent 20,000,000 gross tons. In the Kamerun district an abundant deposit analyses 42.20 per cent. of metallic iron, manganese 0.35 per cent., phosphorus 0.17 per cent., and infusorial earth 12.26 per cent.

CAST-IRON: WITH SPECIAL REFERENCE TO ENGINE CYLINDERS.*

By J. EDGAR HURST, Manchester.

(Continued from page 41.)

Micro-Structure: Influence and Considerations.—It will readily be seen in this connection that the micro-structure of cast-iron is of prime importance. In the first place it will be evident that up to a certain point, as a result of the wearing action on cast-iron, a surface possessing good anti-frictional properties is produced. Even in cast-irons containing no well-defined hard constituents, such as say, for example, phosphide eutectic, the effect of surface disintegration will result in the production of surfaces having good anti-frictional properties. Obviously, however, excessive wear as a means of obtaining efficient liner surfaces is highly undesirable from the point of view of engine power development, and in addition the excessive production of debris resulting from surface disintegration, more particularly in the initial stages of the running of liners, is a contributory cause to "galling or seizure."

The cast-iron having the highest intercrystalline cohesion, otherwise the highest tensile strength, will possess the greatest resistance to surface disintegration, and consequently to wear. Under a given load and speed, therefore, it would appear that wear in engine cylinders is proportional to the tensile strength of the iron. This conclusion was arrived at by Messrs. Ludwig Loewe and Co., Limited, from a series of experiments in which the wear was determined as the loss in weight after rubbing cast-iron cylinders for a given length of time, under a given load and speed, on a hardened steel die.

Cast-iron of the highest tensile strength at normal temperatures is that having the closest-grained structure and a free carbon constituent existing in a very finely divided, or alternately, in a rosette form (1†). Generally speaking, in so far as the tensile strength of cast-iron is concerned, the identity of micro-constituents is of little importance providing the above conditions obtain. Consequently it would appear that the corollary of this statement is true, and that the identity of the constituents is of little moment in the case of wear.

In so far as pure surface disintegration is concerned, and under ideal conditions, this would appear to be perfectly true. The effect, however, of the action of alternating stresses on the character of the surface grains, and the effects of the differential polishing of these grains, largely modified this conclusion, and in this respect the identity of the constituents is of importance.

It is yet too early to state definitely the influence of different constituents on the production of "glazy" surfaces. The greater portion of our knowledge and experimenting in this direction is confined to the behaviour of pure metals only, and its extension to, perhaps, the most complex of all alloys, cast-iron, involves an enormous amount of work.

The extent of the differential polishing of the surface grains in a large measure depends upon the individual characteristics of the grains. (This is dealt with more fully in the next section.) It will be obvious that this effect in excess will rapidly lead to the inauguration of surface disintegration. Cast-irons constituted of large grains, varying widely in physical hardness, are an example of this type of occurrence, and the comparatively rapid wearing of coarse-grained irons, consisting largely of ferrite and phosphide eutectic, is in a large measure due to this cause.

The influence of wear in the production of surfaces of good anti-frictional properties on cast-iron has to a large extent been fully dealt with. The influence of the general micro-structural arrangement on one or two points is of importance. Figs. 10 and 11 overleaf are photographs of polished and etched specimens of two samples of cast-iron. A beautiful network arrangement of the phosphide eutectic and cementite is revealed in Fig. 10, whilst in Fig. 11 a blotched appearance is noted which, in this case, consists of large ferrite areas, around which the hard constituent is indiscriminately distributed. (See Fig. 12.) Under wear the resulting surface produced in such an iron as represented by Fig. 8 (page 41 *ante*), will be obviously ideal, consisting of a most even distribution of the minute reservoirs for the oil. Such structures as these are produced very readily in chilled liners (See Section III), and this probably accounts for the excellent anti-frictional properties of such liners. The micrograph (Fig. 4, page 40 *ante*) shows the character of surface produced in such liners. In the other case, represented in Figs. 10 and 11, such a micro-structure of fairly large grain size is typical of a comparatively fast-wearing liner, although at the same time possessing good anti-frictional properties.

It must not be assumed that the presence of the hard constituent, structurally free, however, is absolutely indispensable for the production of a good wearing and running liner, and, in fact, cast-irons of very low phosphorus content and containing practically no structurally free hard constituent give excellent results in this respect. The study of the influence of pearlite in this respect is still under investigation in greater detail, and undoubtedly its influence is very important. Qualitatively it may be explained in part somewhat on the following lines. Pearlite consists of numerous very fine lamellæ of the two micro-constituents ferrite and cementite, which in individual properties represent the two extremes. The result of the polishing action on such a structure is the production of a surface containing very fine microscopic channels. Such channels behave in exactly a similar manner as fine capillary threads, distributing the lubricant undoubtedly by means of surface tension.

Hardness and Wear.—The lack of any means whereby

* Paper read before the Manchester Association of Engineers, on Saturday, December 9, 1916.

† See Bibliography.

the wearing properties of any material can be tested and readily adjudged is sorely felt by both engineers and metallurgists alike. It is customary to use the hardness number, which is, as a general rule, obtained by the Brinell method, as a means of indicating the wearing properties of metals.

As applied to cast-iron for the purposes of engine cylinders, this method is far from satisfactory. Cast-irons giving the same hardness numeral often wear at widely different rates, and, furthermore, the influence of the presence of such elements as manganese and chromium, which in normal percentages are not detected by the hardness numeral, is most important.

The unsatisfactory nature of the Brinell hardness numeral in this capacity is undoubtedly due to a multiplicity of causes.

In the first place an enormous amount of uncertainty surrounds the definition of hardness, and it is very doubtful whether the methods of determining hardness actually do determine this property in its entirety. The hardness of a body as defined by the nomenclature committee appointed by the Iron and Steel Institute (2) is "the resistance offered by a body to the 'mechanical' separation of its particles." It would appear from this definition that hardness and wear are very intimately associated. Indeed, it is the author's opinion that in a homogeneous material the true hardness property is its resistance to wear. From this, therefore, the resistance to wear is a function of the cohesion of the particles, or rather, in the light of more recent knowledge concerning the architecture of crystalline bodies, is the resistance to deformation, and it is therefore tentatively suggested that the yield-point gives the more correct indication of the true hardness. The high resistance to wear of some of the non-ferrous alloys, *e.g.*, anti-friction alloys, is in all probability due to their liability to produce under the influence of stresses during working overstrained superficial layers. The investigation of the yield-point in this connection will doubtless throw much more light on this hitherto somewhat neglected subject.

To return to cast-iron. It is extremely probable that wear due to surface disintegration is not exactly wear in the above sense, but is really a function of the brittleness of cast-iron. The abrasion or relief polishing previously outlined is the true wear in that it depends upon the resistance to deformation of the individual component grains. The whole subject, particularly in reference to the material cast-iron, it will be plainly evident, is extremely complex and involved, and an enormous amount of work still remains to be done.

The Brinell hardness test as applied to cast-iron is most unsatisfactory, and it is practically impossible to correlate the figures obtained in this test with the chemical constitution of the cast-iron. Broadly speaking, the hardness numeral varies with the combined carbon content. The presence of such hard constituents as phosphide eutectic increase the numeral. This can only be truly said of cast-irons obtained under exactly identical conditions. In such a complex alloy as cast-iron this is not at all surprising, and is in all probability to be explained by the numerous subsidiary influences, chiefly the casting temperature and the rate of cooling, which largely affect the structural arrangement and distribution and the grain size.

Table I, on the next page, shows the influence of casting temperature on the Brinell hardness figures and also the ultimate stress figures of three different grades of commercial cast-iron. The hardness figures apparently bear no relation to the tensile figures, though roughly they vary with the slight change in carbon content. Apart from the casting temperature, the above bars, as far as possible, were obtained under strictly identical conditions.

This aspect of the relation of the Brinell figure to the other mechanical tests is simplified in Table II, in which a series of analyses and complete mechanical tests are included. The impossibility of correlating the hardness numeral with either the other mechanical tests or the chemical constitution is clearly evident.

This difficulty is doubtless largely due to the permanent bodily slip of the crystals under compression owing to the presence of the free carbon constituent, and as a result it can only be considered that Brinell figures on cast-iron are at all comparative when the conditions under which the specimens are obtained are strictly identical.

Machining.—It is interesting at this stage to turn our attention to the effect of machining on the resulting liner surface.

It will be clearly evident that a similar surface disintegration, although much more severe in degree, is to be expected as a result of machining. Owing largely to the weak intercrystalline cohesion of cast-iron under the influence of the cutting action of the tool, there will be a tendency for cracks to develop and travel along the crystal junctions. The extent to which these cracks will develop will depend largely on the strength of the iron and the force or severity of the machining. Professor Poliakoff has shown that the quality of finish, or shall we say surface, of a given material varies with the cutting speed: "the quality of the finish improves as the cutting speed decreases." (3)* The deteriorating action of the rate of machining on the surface character of metal is more pronounced in the case of cast-iron than in steel. The two micro-photographs, Figs. 13 and 14, are taken from a cast-iron liner surface, and show the effect of machining with widely different cutting feeds. The difference in the depth of the holes and the extent of the surface cracks will be noticed.

It is extremely fortunate that the extreme accuracy necessary in liners and cylinders requires very careful machining, which must necessarily proceed at a comparatively slow rate. However, whatever the rate of machining, surface cracks and holes are found to a more or less extent. Such surfaces are very liable to rapid surface disintegration, at least for a time, and in addition to the delay in the production of the glazed surface the resulting excessive amount of disintegrated material is very liable to cause seizure. For this reason the comparatively recent method of internal grinding is a more preferable method of finishing liners than machining. Grinding has another aspect of great value in this connection. The glazing effect of the grinding wheel on the

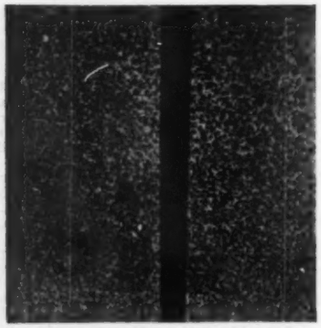


FIG. 10. CAST-IRON, POLISHED AND ETCHED; MAGNIFIED 250 DIAMETERS.

FIG. 11. CAST-IRON, POLISHED AND ETCHED; SOMEWHAT REDUCED.

FIG. 12. MICRO-SECTION OF FIGURE; ETCHED WITH PICRIC ACID; MAGNIFIED 250 DIAMETERS.

FIG. 13. CAST-IRON; MACHINED SURFACE; MAGNIFIED 48 DIAMETERS.

FIG. 14. CAST-IRON; MACHINED SURFACE; DEEPER CUT THAN FIG. 13; MAGNIFIED 48 DIAMETERS.

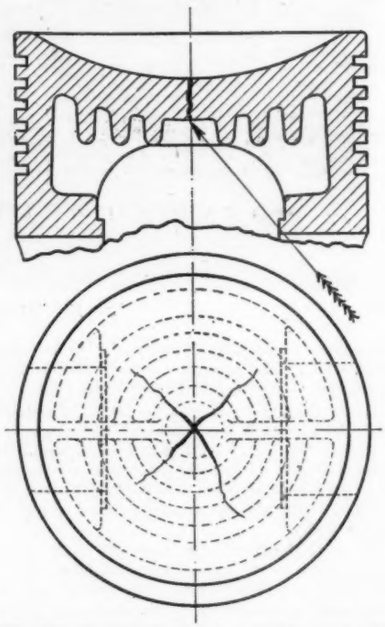


FIG. 15. DIESEL ENGINE PISTON HEAD, SHOWING STAR CRACKS OPENING OUT FROM CENTRE.

* See Bibliography.

surface of the material is a phenomenon of the class already dealt with, *i.e.*, surface flow. It is also possible to produce appearances on the liner surface, by means of the grinding wheel, identical with those produced by a seizure. In addition the surfaces of liners which have been ground often possess in a degree the glazy appearance or very finely granular flowed structure. This is a distinct advantage, and in addition affords a means where by the influence of this type of surface can be further investigated.

SECTION II.—ON GROWTH. GENERAL CONSIDERATIONS.

After prolonged exposure to high temperatures certain cast-irons are found to have undergone a permanent increase in volume. Percy, in his work on iron and steel, noted this fact, and incidentally suggested that this property could be rendered of practical utility in, for example, the rendering serviceable of cannon shot which had been cast too small in size. Of later years this question of permanent distortion and change in volume or growth was first brought seriously to the front by Alexander Outerbridge (4), and was afterwards subjected to rigorous investigation by Messrs. H. F. Rugan and H. C. Carpenter (5 in Bibliography).

These investigators showed that the increase in volume takes place with greater rapidity and to a greater extent if the heating to which the cast-iron is subjected be intermittent. The temperature at which growth appeared to commence was about 650 deg. C., and it reached a maximum at about 750 deg. C. At higher temperatures than this, say 900 deg. C., very little further expansion was noted. The growth reached its maximum at any given temperature in the specimens used after a period of three hours' heating; and continued heating over a period of 17 hours did not appear to make any appreciable difference. In addition to the gradual increase in volume a gradual increase in weight was also noted.

They established the facts that (1) alloys not containing graphite do not grow, and (2) that alloys containing graphite are, under suitable conditions, capable of growing, and further, that the total growth is roughly proportional to the silicon content.

The total growth was far in excess of that caused by the dissociation of the carbide and the precipitation of temper carbon. This is recorded by Dr. Hadfield as being about 3 per cent. in those irons in which complete precipitation of the carbon in this form has taken place. The dissolved or occluded gases were also shown to have an influence on the final growth. It was proved that the growth was largely due to the influence of the furnace gases, which penetrate into the cast-iron by way of the graphite plates, and whilst in the hot state oxidise primarily the iron, and subsequently the silicon and phosphorus. Curiously, the graphite or free carbon appears to be the last constituent to be oxidised (6).

A proof positive of the influences at work is to be found in the fact that on heating cast-iron in a vacuum no expansion, but a slight shrinkage in volume, takes place; the same cast-iron on heating in furnace gases expanded somewhere about 67 per cent. in volume.

Growth at Low Temperatures.—Cast-iron fittings, such as pipes and valves on superheated steam mains, after having been in actual service for some length of time, have been noted to deteriorate seriously. A marked falling off in tensile strength, accompanied by slight permanent distortion and changes in volume, takes place, and occasionally cracks have been developed.

The average temperature to which such fittings are exposed is about 300 deg. C. It is still very uncertain what is the exact mechanism of the changes taking place at such low temperatures.

Growth in Engine Cylinders.—In the internal combustion engine, in particular, the material is constantly subjected to increased and varying temperatures, and the study of the behaviour of grey cast-iron under increased temperatures hence becomes of great importance.

As a general rule, in internal combustion engines, the liner itself does not become unduly heated, owing largely to the efficiency of the cooling arrangements. At the same time it is undoubted that the temperature of at least the inner surface of such a liner, during actual working, is approximately in the region of from 200 deg. to 300 deg. C.

In the Diesel oil engine the centre portion of the piston head is very often raised to quite a red heat, owing to direct contact of the piston head with the flame. This state of affairs is to be observed in gas engines; and in such engines working at full load the piston head can be seen to have a dull glow in the dark. In the gas engine the temperature attained by the piston head is not nearly so high as is the case in the Diesel engine.

After some time such overheated pistons become pitted and scaled in the heated area, and frequently crack in a manner as illustrated in the sketch, Fig. 15, the star cracks radiating from the centre of the heated area.

Heat-Treatment of Grey Cast-Iron.—Thoroughly to understand this phenomenon it is necessary to become actually acquainted with the changes which take place in grey cast-iron on heat-treatment.

The effect of heat-treating grey cast-iron has been investigated by Dr. Hatfield (7). In his experiments grey cast-iron bars were exposed for several hours to a temperature of 900 deg. C., and slowly cooled over a period of 48 hours. A very serious falling-off in tensile strength was noted, the tensile strength being reduced from eight to twelve tons in the "as-cast" condition to three tons per square inch after heat-treatment. (This is of great importance in view of the growing practice of annealing cast-iron castings for softening purposes.) An examination of the micro-structures before and after heat-treating revealed the fact that in the as-cast specimens the graphite existed "in clear-cut worm-like forms," whereas in the heat-treated specimens "the graphite structure would appear to have swollen," which is "no doubt due to the free carbon produced by the dissociation of the carbide in the pearlite being drawn into position alongside the already existing graphite plates."

These results have been confirmed by the author, and figures are given in Table 3 overleaf. The rapidity with which free carbon is precipitated even at so low a temperature as 650 deg. to 700 deg. C. is most striking. It is interesting to note that in the high-phosphorus bars the rate of dissociation is somewhat retarded. This is confirmed on examination of micro-specimens from the above test bars, when it is found that the last of the pearlite remaining is that in juxtaposition to the phosphide eutectic. This is interesting to note, for

FIG. 16. NORMAL SPECIMEN, SHOWING GRAPHITE ARRANGEMENT; UNETCHED; MAGNIFIED.

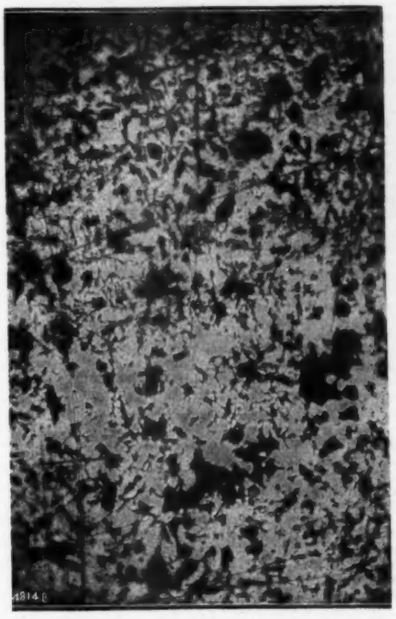


FIG. 17. HEAT-TREATED SPECIMENS, SHOWING SWELLING OF GRAPHITE PLATES; UNETCHED; MAGNIFIED.

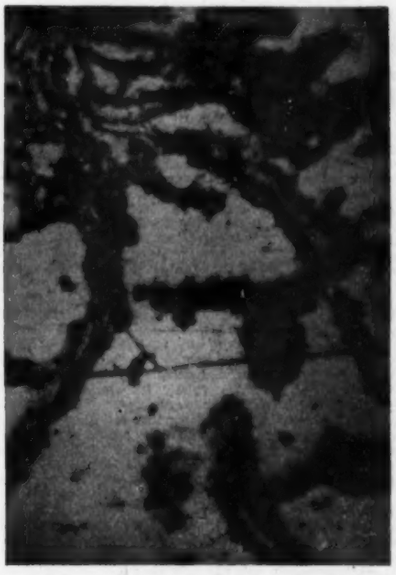


FIG. 18. MAGNIFIED 250 DIAMETERS; UNETCHED.

TABLE I.

Test No.	Analyses. CC. per cent.	Gr. per cent.	Si per cent.	Mn per cent.	S per cent.	P per cent.	Casting Tem. Deg. C.	Tensile Strength, tons sq. in.	Brinell Numeral.	Remarks.
1	0.44	2.97	—	—	—	—	1,320	Defec.	228	Blast pressure.
2	0.37	2.80	—	—	—	—	1,300	10.5	217	
3	0.38	3.02	—	—	—	—	1,250	10.7	196	17 in. H_2O.
4	0.35	3.00	2.24	0.71	0.137	1.84	1,190	11.0	207	
5	0.45	3.21	1.86	0.93	0.11	—	1,300	12.8	241	
6	0.43	2.96	—	—	—	—	1,250	13.0	196	
7	0.40	2.63	—	—	—	—	1,200	10.65	241	
8	0.46	2.65	—	—	—	—	1,190	10.7	228	Did not run.
9	0.50	2.66	1.73	0.72	0.12	0.68	1,360	12.8	241	
10	0.50	2.45	—	—	—	—	1,290	13.4	196	
11	0.51	2.27	—	—	—	—	1,250	11.85	137	
12	0.55	2.50	—	—	—	—	1,190	13.2	196	Hardly run.

TABLE II.

Mark.	CC.	Gr.	Total C.	Si.	Mn.	S.	P.	Transverse Strength. Size of Bar.	Cwts.	Deflection.	Tensile Strength. Section.	Tons per sq. in.	Brinell Numeral.	Remarks.
								In.		In.	Sq. in.			
1	0.56	2.87	3.43	1.51	0.69	0.15	0.52	2 × 1 × 12	97.7	0.12	0.798=5	10.5	207	
2	0.55	2.92	3.47	1.64	0.66	0.137	0.54	2 × 1 × 12	88.5	0.11	0.798=5	12.4	217	
3	0.45	2.73	3.18	2.11	0.93	0.134	0.57	2 × 1 × 12	98.8	0.12	0.798=5	10.5	228	
4	0.48	2.88	3.36	1.98	0.94	0.104	0.47	2 × 1 × 12	86.8	0.11	0.798=5	12.0	217	
5	0.43	3.34	3.77	2.02	0.99	0.132	0.60	2 × 1 × 12	97.4	0.12	0.798=5	12.5	217	

it is generally found in grey foundry irons that some of the pearlite patches are in some manner connected with the phosphide eutectic, and are found in juxtaposition. In addition the graphite plates appear to have swollen, as pointed out by Dr. Hatfield.

TABLE III.

Specimen Mark.	Analyses. CC.	Gr.	Total C.	Si.	Mn.	S.	P.	Remarks.
E1	0.50	3.35	3.85	1.87	0.834	0.05	0.016	
E2	0.50	3.51	4.01	1.79	0.742	0.05	0.106	
E3	0.47	3.17	3.64	1.87	0.77	0.05	0.43	
E4	0.44	3.08	3.52	1.89	0.44	0.05	0.85	

AFTER HEAT-TREATMENT.

—	E1.	E2.	E3.	E4.	Treatment.
	Per cent.	Per cent.	Per cent.	Per cent.	
Gr.	3.72	3.62	3.33	3.29	750 deg. C. for 2 hours, quenched in water.
Gr.	3.85	3.96	3.61	3.53	750 deg. C. for 4 hours, quenched in water.
Gr.	3.73	3.63	3.50	3.51	900 deg. C. for 2 hours, quenched in water.

Examination of the micro-structure of the heat-treated specimens reveals interesting results. Figs. 16 and 17 show the appearance of the free carbon before and after heat-treating. In this instance the specimens were quenched following upon the heat-treatment, thus preserving in some measure the actual structure at this high temperature. The apparent swelling out of the graphite plates, leaving cavities, is particularly noticeable. A similar swelling out of the graphite plates was observed by Messrs. Rugan and Carpenter in the unoxidised centres of partially grown cast-iron bars.

The swelling out of the graphite and also the partial liquation of the phosphide eutectic is admirably illustrated in Fig. 18. This specimen has been cut from a high-phosphorus cast-iron bar, heated to 890 deg. C. for a protracted period. The distinctly granular appearance of the pearlite is a characteristic feature of the heat-treated cast-irons. The lamellar character of the pearlite is rapidly lost, and changes either into a "bead-like" or granular form, according to the temperature maintained during heat-treatment and the rate of cooling of the specimen.

The swelling out of the graphite plates was attributed by Carpenter and Rugan to the penetration of the furnace gases into the centre of the cast-iron, and they also considered that the minute explosions of the dissolved hydrogen in the cast-iron and the oxidising gases may assist in the expansion.

It is interesting to note the extreme rapidity with which the swelling out of the graphite takes place. The photograph, Fig. 17, is taken from the centre of a specimen 2 in. by 1 in. by 1 in., which was heated for 60 minutes before quenching.

The changes taking place in the Diesel engine piston top, when subjected to the heating action of the flame during working, will now be clear. In the first place the expansion of the graphite plates, due to the entry of the oxidising gases, and simultaneously, the dissociation of the pearlite carbide and the precipitation of temper carbon takes place.

As a result of these internal changes, which take place only in a localised area of the piston top, the iron is rendered, locally, considerably weaker, and large internal strains must undoubtedly be set up.

As a matter of fact, however, the ultimate cracking of Deisel engine piston tops can, as a general rule, be traced to the phosphorus content of the cast-iron, and providing this is kept sufficiently low this troublesome cracking is practically eliminated. In all probability this is due to a number of causes, the chief of which are set out below. In the first place, locally, at the centre of the star crack and in a superficial layer, the temperature attained by the cast-iron is probably very high, at least in the region of 900 deg. C. Specimens taken from this portion distinctly show liquation of the phosphide eutectic. This will undoubtedly increase the magnitude of the internal strains, and in addition at points in the region of this centre this same eutectic, at these temperatures, will be perilously near its liquation point. Both the elements, phosphorus and silicon, have a profound influence on the swelling out of the graphite plates. This influence is not yet thoroughly completed. Suffice it to say that to counteract this troublesome cracking the amounts of these elements present should be kept at a minimum. Furthermore, at high temperatures it is certain the high-phosphorus cast-iron is considerably weaker than low phosphorus cast-iron, and under the influence of the high alternating gas pressures attained in the Diesel cylinder, such material will readily develop the star cracks.

Strictly speaking, however, this cracking is not actual "growth," for as a general rule very little oxidation beyond a superficial layer only can be detected. The change in volume which must necessarily take place, owing to the expansion of the graphite, is very slight in the piston as a whole, owing to the localised character of the heating, and is undoubtedly in a large measure responsible for the internal stresses. On cooling down such heat-treated cast-iron the swelling out of the graphite plates is in a large measure recovered, and particularly in the low phosphorus irons, apart from the deposition of the temper carbon, which appears to be drawn alongside the graphite plates, these plates assume nearly their original form.

Briefly it can be taken that the changes which have taken place in such heated and cracked Diesel engine piston tops are the very preliminary changes, previous to any oxidation, taking place in the well-known growth phenomena.

(To be continued.)

NOTES FROM THE UNITED STATES.

PHILADELPHIA, January 4.

RECENT estimates of steel exports for the year just closed show that less than 25 per cent. of the steel production went abroad. The general inference has been that the percentage was much higher, and even this percentage was maintained by discouraging the presentation of domestic requirements. The railroad needs for steel were abnormally below the average. In 1907, 7,000 engines were ordered, and last year only 3,000, owing to the discouraging influences to which railroads have been subjected by unfriendly legislation and over-exacting Commissions. Last year the railroads ordered 170,000, in 1915, 107,000; in 1907, 284,000. Domestic requirements have, through apprehension or necessity, been greatly reduced for two or three years. During this time an enormous amount of mill, shop and factory equipment has been so worn out that a general restoration will be necessary, and more or less used machinery is being picked up. When the European demand for munitions set in, some manufacturers installed convertible machinery, which, when necessary, can be adapted to domestic uses; the country at large, while not short of machinery, is bound to generate such a demand as to create unusual activities along all diversified equipment lines, which will make engineering plants, machine and tool shops and foundries the centres of restorative activities. It would be guesswork to say how much money was expended on improvements. The United States Steel Corporation early in the year set aside 100,000,000 dols., and the Bethlehem Company has recently exceeded these figures; scattered steel forces have been concentrated, embargo steel hinders steel production. Large quantities of freight are held up on mill sidings; some mills shut down a few days to let the glut be cleared. The coke supply is shorter and more furnaces are banked. No effort has been made for months to get new business, and it is ready to pounce on capacity. But, after all, there is of late a feeling of more patience and disposition to take chances on the unexpected happening.

AMERICAN SUBMARINES.—Admiral Taylor, Chief of the American Bureau of Construction and Repair, says the *Iron Age*, foreshadows the early standardisation of complete designs for submarines. Last year a design for a fleet submarine was prepared and issued to bidders, but no bids were received thereon, the contract being awarded on the basis of the bidder's design. This year, however, the Naval Bill contemplated the inclusion of three submarines of about 800 tons, this being the size recommended strongly by the commander of the submarine force. The design of one of these vessels has been practically completed by the Bureau, and it is the intention to build this vessel in a Navy yard. The other two 800-ton submarines have already been contracted for in private yards. Work on all these vessels will be rushed, with a view to obtaining from the results of their trials data in regard to the comparative value of the different types, with the object of selecting that which proves most efficient under service conditions.

DECOMPOSITION OF CAST-IRON.—In the "Mitteilungen des Materialprüfungsamts, 1916," Professor O. Bauer and Dr. E. Wetzel give a summary of their recent researches on the decomposition of cast-iron, comprising by the term decomposition the disintegration phenomena, similar to ordinary rusting, to which iron is subject, including so-called graphitising, iron cancer, spongy decay, &c. Such a summary is not likely to raise novel points. The primary condition for the decomposition of cast-iron—grey and white, whether graphite be visible or not—is always the presence of liquid water. Electric currents, to which the iron is anode, accelerate the decomposition very much; hence contact with many other metals should be avoided. Thermo-electric currents are also injurious; but there is very little statistical material available as to their action. Salt water is much more injurious than purer water (distilled, supply water, rain water). But the decomposition does not require any electrolytic action; it will also take place, at much slower rate, in their absence. The decomposition products, which are largely hydroxides, are only partly found *in situ*; much of the iron, manganese, silicon, &c., may be carried away. The residual products may accumulate between the non-corroded scales of graphite, and may form more or less soft masses, which harden especially on drying, together with the lime and other minerals from the water or ground. The graphite, and also the cementite (in white iron), binds these products together. When the iron is exposed to flowing water, all the products may be washed out; for this reason, probably, there is little appearance of decomposition, except a fairly uniform thinning, and occasionally local rusting, on the inside of conduits and pipes, whilst the outside wall may be badly decomposed. In liquid water at rest, in moist ground, sand, &c., the decomposition products accumulate. In grey iron the decomposition proceeds from the scales of graphite. This graphite may itself appear to be corroded, as it looks light grey, because it reflects the light better than the oxidic products; but the graphite, of course, is not attacked. Protective coatings of paint, &c., answer as long as the protective skin is intact and continuous. The best way of preventing decomposition of cast-iron is to exclude liquid moisture.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—With the complete resumption of work after the holiday it is evident that the extreme pressure in the steel trade is destined to continue as long as the war does, whatever may happen afterwards. Directly or indirectly the purposes of the war monopolise practically the entire production of finished and semi-finished steel. In this connection it is interesting to note that when the new furnaces which are rapidly nearing completion are once in full blast there is every prospect that the output of semi-finished steel will be largely augmented, a circumstance of considerable importance at the present time, when the demands are so insistent, and when makers find it increasingly difficult to maintain the output at the requisite level. Mercantile business is being further curtailed, but even this seems to make no appreciable difference. The first call is still for sheet steel, then comes the material required by the Admiralty, and the additional wants of the Ministry of Munitions, so that when these are supplied but little remains for any other customer.

Scotch Pig-Iron Trade.—The demand for pig-iron of all grades is, if anything, on the increase, hematite still being in great request. Meantime there is no possibility of accumulating stock, as every ton goes direct from the furnace to the rolling-mill, and still the cry is for more, the steady and excessive output notwithstanding. More and more, too, all sources of supply have been diverted to war work, with the result that practically no shipments to neutral countries are being carried through, licences for the export of foundry iron having been reduced to the minimum, while for the export of hematite they are almost non-existent. For export, prices remain unchanged, and, despite vague rumours to the contrary, there is little or no immediate prospect of any alteration in the minimum rates for home consumption.

Advance of Steelworkers' Wages.—An application for an advance of wages having been made recently by the members of the Amalgamated Society of Steel and Iron Workers of Great Britain, Sir Thomas Munro, who acted as arbiter, has just intimated his decision. His recommendation is that, dating from the first full day after November 15 last, all workers whose wages are 2*l.* per week and over shall receive an advance of 15 per cent., and that those whose wages are below that figure shall receive an advance of 10 per cent., this making a total advance of 20 per cent. since the outbreak of war. It is further recommended that time and a half should now be paid for week-day overtime, and that for Sunday overtime the rate should be double pay.

Pooling of Labour in Clyde Shipbuilding Yards.—An interesting scheme has just been discussed at a conference held between delegates from the Employers' Federation and the shipbuilding and engineering trades, and representatives from the Board of Trade, whereby it is confidently expected that it may be possible to speed-up the completion of a number of cargo steamers at present in course of construction. To combat the shortage of labour in various yards it has been suggested that, with the consent of those most intimately concerned, the services of skilled workmen might be temporarily transferred from one establishment to another when the urgency of the work in hand required additional labour to accelerate its completion. By the projected arrangement the men concerned would still remain employees of their original firm, be paid by them, and return to them as soon as the work was completed. In the successful carrying out of the scheme no material difficulty is anticipated, and the advantages to be gained are certainly very considerable.

THE TRADE OF FRENCH INDO-CHINA.—According to the *London and China Telegraph*, the latest official report on the economic position of French Indo-China shows a quite satisfactory state of affairs, in spite of the war. The trade figures for 1915, while registering a decline on the previous year, are still in excess of 1913, and there has been considerable commercial activity during the past year. The mining industry of Tong-King, for example, has developed, notwithstanding the war. The Tong-King coal mines, which exported 260,000 tons in 1907 and 533,000 tons in 1914, produced 630,000 tons in 1915. The exports of the zinc mines have not ceased to increase, and they reached 33,335 tons in 1915. But what is more remarkable still is the fact that in spite of the lack of capital, the shortage of labour in certain regions, and the difficulty of transport, the French colony has continued, generally speaking, to progress. Thus Cochin China has developed the culture of the rubber tree in the midst of war. There is, however, a serious drawback which the war has prevented from being remedied, and that is the absence of the scientific organisation of agriculture. It is known that on this point Indo-China is very much behind, compared with the neighbouring British and Dutch colonies. The scientific study of rice-growing, says *Le Temps*, is a pressing necessity, but, unfortunately, the official charged with this matter is now serving with the French Army, and much delay is likely to ensue. The culture of maize and coffee is not being dealt with until this year. These questions are all the more important in view of the fact that the French colony now has to meet the friendly competition of Japan. Comparing the first two months of 1916 with the corresponding period of 1915, we see that the Japanese exports into Indo-China were more than quadrupled. Our French contemporary, therefore, urges that Indo-China trade circles should look to their laurels.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—There is no outward change in the position on the week. The heavy demand for manufacturing fuels of all descriptions continues, collieries having many orders on hand for both home and export trade. Best steam hards are coming forward in slightly heavier quantities, but with the requirements of inland works, railways and other industrial users so great, there is little available for neutrals. The scarcity in steam nuts prevails, but there is promise of an easier position in the course of a few days. Cobbles and slacks are very active. Contractors are taking all possible supplies of gas fuel, and the open market has not much left to offer. Cokes are very tight, the blast-furnace brands particularly so. In the house coal section the demand has risen perceptibly with the increased severity of the weather. Quotations:—Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; smalls, 7*s.* 6*d.* to 8*s.* 6*d.*

Iron and Steel.—The output is being maintained on a very satisfactory level, for all branches of the Sheffield industries are working at top pressure. The steel production is gradually being expanded. This does not permit more to go for private trade purposes, but meets the ever-growing call for work of national importance. The material market possesses a firm tone without any arresting features. The supplies are in large quantities, trade is brisk, and top prices invariably rule. The increasing of the tonnage of hematites is still proceeding. Finished goods of all descriptions are now wanted in large numbers, but it is not expected that the current quotations will show any appreciable alteration for some time to come. Shipbuilding material is much sought after. The acceleration of the output of merchant tonnage has had a big influence upon several prominent local firms for some time past, and they are making praiseworthy efforts to fulfil all requirements. The demands, however, are phenomenally high, and have resulted in many schemes of alteration and extension being entered upon. Nearly all the large undertakings have in hand or contemplate some improvement or workshop addition. Tramway work is still plentiful, and makers of railway steel possess an abundance of orders. There is little indication of a falling-off in the file trade, inquiries for all shapes and sizes coming to hand with great freedom. Russia is stated to be in the market again for large supplies, with delivery early in the spring. Saws are also wanted in large quantities. The national scheme of land cultivation continues to find more work for the already busy agricultural engineers. The demand just now for all classes of implements and machines is very heavy, and it is inevitable that many would-be customers will be disappointed in the spring. Makers complain that there is great difficulty in securing steel for producing spades, hoes, rakes, &c. They are pressing for a removal of the embargo, and are confident of convincing the authorities of the necessity. Overseas trade flourishes despite many difficulties. Indents have arrived for tools, saws, files, springs, cutlery, electro plate, and steel.

The Cutlery Trade.—Mention was made in these notes a week ago of the appointment of a deputation of the cutlery manufacturers to interview Dr. Addison on the matter of steel for cutlery products. This duly went on the 11th inst., and laid before the Minister of Munitions the difficulties which would confront the trade if no crucible cast or open-hearth steel were permitted to be used. It was asserted that the proposed substitute of shell discards was valueless for the making of any articles with a cutting edge, and that unless some concession were made, the cutlers would be faced with the alternative of closing down. Emphasis was laid on the valuable character of the business Sheffield cutlers did all over the world, the number of people who received employment through it, and the imperative necessity of to-day consolidating positions won in erstwhile German markets. A reply was promised, and is being awaited with some degree of apprehension lest it should prove unfavourable. The electro plate trade and silversmiths temporarily abandoned their deputation on the copper question at the last moment, on advice from Colonel Hubert Hughes, chairman of the Chamber of Commerce. This gentleman himself, being in town, laid the grievance before Dr. Addison, whose answer is yet awaited. It is not out of place to air another grievance here. The Cutlers' Company has issued a warning this last few days on the question of cutlery marking. It is stated that much cheap and common cutlery is being sent out marked or labelled as "Best Sheffield Cutlery," "Superior Sheffield Cutlery," &c., and unaccompanied by the name of the maker. The injurious effect of such a practice is reacting upon trade as a whole. Travellers from foreign countries have used it to demonstrate to potential purchasers the depth of bad quality to which Sheffield "Best" or "Superior" has descended. With the reputation of the city at stake, the Cutlers' Company has decided to take whatever legal action is open to it against offenders who are discovered.

Death of Colonel Hughes.—Death has removed one of Sheffield's most popular and energetic business men in the person of Colonel Hubert Hughes, who died in London on Tuesday afternoon with tragic suddenness. The deceased gentleman, who was 63 years of age, was the leading partner in the firm of Younge, Wilson and Co., solicitors, but he was more widely known for his other activities. As chairman of the Sheffield Chamber of Commerce he did much to organise and weld together the city's business interests, whilst in the capacity of chairman of the local Munitions of War Committee, he lent valuable aid to the Government from the onset of war. As a director of Messrs. Wm. Jessop and Co., Limited, he had more than a passing acquaintance with the steel trade. He also had similar business interests abroad, particularly in Russia. The cause of education was very dear to him, and he made great efforts in assisting the establishment of Sheffield University. A widow and three daughters are bereaved.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The Cleveland pig-iron market is quiet, but steady and very firm. Recent persistent bad weather has interfered considerably with shipments, and as a consequence the quantity of iron available for home consumption has become more than ample, and one or two firms of producers are accumulating a little stock. Good inquiries are reported both on home and Continental account, and a large export business could be done if licences and tonnage were forthcoming. A further increase of a dollar and a half in American iron will render more difficult transactions between America and Scandinavia, in which some Cleveland houses, with the permission of the British Foreign Office, have been interested. This brings the price of No. 2 Northern iron up to approximately 141*s.* 9*d.* at the works, to which a freight of 130*s.* has to be added. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge all stand at 87*s.* 6*d.*, and No. 1 is 91*s.* 6*d.*; whilst for despatch to our Allies No. 3 is quite 98*s.*; No. 4 foundry, 96*s.* 6*d.*; No. 4 forge, 95*s.* 6*d.*; and No. 1, 102*s.* 6*d.*; and for shipment to neutral countries minimum rates named are 105*s.* for No. 3, and 110*s.* for No. 1. Scandinavia and Holland are prepared to pay high prices for No. 3.

Hematite Iron.—Very satisfactory accounts are given of the East Coast hematite branch of the staple industry, so far as home trade is concerned. Consumers experience no difficulty in obtaining what they require, and they report very ample and regular supplies coming in. Export business, however, is stagnant, as licences to ship recent sales are withheld until some of the arrears of shipments on contracts made some little time ago are worked off. Prices are firmly held. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, 137*s.* 6*d.* for shipment to France, and 142*s.* 6*d.* for export to Italy.

Stocks and Shipments of Pig-Iron.—Makers' stocks of pig-iron are very small. The quantity of Cleveland pig in the public warrant stores has now fallen to 3,498 tons, composed of 3,462 tons of No. 3 quality and 36 tons of other descriptions of iron deliverable as standard. Since our last report 100 tons of No. 3 have been taken from the stock, and so far this month the store has been reduced by the withdrawal of 240 tons of No. 3. Shipments of pig-iron from the port of Middlesbrough so far this month amount to 12,109 tons, as compared with 17,785 tons to the same date last month, and 15,607 tons for the corresponding part of January last year.

Foreign Ore.—Large quantities of foreign ore are coming to hand. For the first half of the month the unloadings at the port of Middlesbrough amount to 98,720 tons.

Coke.—Demand for coke is heavy, and prices are very stiff. Local consumption is large, and promises to increase in the near future, so that the production of coke is likely to be fully absorbed for some time to come. The fixed maximum of 28*s.* at the ovens remains the market rate for average blast-furnace kinds, and up to the limitation price of 30*s.* 6*d.* at the ovens continues to be named for qualities low in phosphorus.

Manufactured Iron and Steel.—Producers of finished iron and steel are very busily employed. The output of mercantile shipbuilding material has now assumed very considerable proportions, and is still steadily growing. Principal market quotations to home customers stand:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* to 18*l.*; packing iron and steel (parallel), 12*l.*; packing iron and steel (tapered), 14*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 19*l.* to 20*l.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

MILD STEEL FOR LOCOMOTIVE FIRE-BOXES.—The *Zeitschrift des Vereines Deutscher Ingenieure* of September 9, 1916, contained an article on the use of mild steel for locomotive fire-boxes, by Dr. Kittel, dealing particularly with tests conducted in the Technical High School at Stuttgart, with a very pure iron, a speciality of Krupp's works. This iron showed little of the critical temperature range, during which steels are apt to fail. In the issue of the same journal of November 25, Director Busse, of the Danish State Railway department, commenting on this article, says that he introduced mild steel fire-boxes 20 years ago, taking first American and then Krupp steel; the latter had answered better than the former. The tubes were expanded into the boxes with the aid of copper ferrules. Visiting the United States lately he had observed that repairs of fire-boxes were tolerated over there which European practice would hardly pass, and that on the whole, perhaps, the life of a fire-box depended more upon the way in which it was built and treated than upon the material.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Since our paragraph on page 33 of our last issue tonnage has been arriving and shipments have been on the increase. There remained, however, a certain uneasiness, pending developments in connection with the Board of Trade action in regard to shipping, and pending also the decision of the London meeting of the Central Executive Committee for the supply of coal to France and Italy. Apart from the best Admiralty large and best seconds, which remained nominal, quotations for steam coal are:—Secondary qualities, 29*s.* to 30*s.*; Black Veins, 29*s.* to 30*s.*; Western Valleys, 28*s.* to 29*s.*; Eastern Valleys, 26*s.* to 28*s.*; best bunker smalls, 19*s.* to 20*s.*; cargo smalls, 12*s.* to 18*s.* In bituminous coal, best households at pit made 25*s.* 6*d.* to 26*s.* 6*d.*; No. 3 Rhondda large, 28*s.* to 30*s.*; No. 2 Rhondda large, 25*s.* to 26*s.*; and smalls, 21*s.* to 22*s.* Patent fuel made 35*s.* to 37*s.*; whilst, for export, special foundry coke made 62*s.* 6*d.* to 65*s.*; good foundry coke, 57*s.* 6*d.* to 60*s.*; and furnace coke, 47*s.* 6*d.* to 52*s.* 6*d.* The quotation for pitwood, ex ship, was 54*s.* to 55*s.*

Western Trade Matters.—The directors of the Field Line (Cardiff), Limited, have issued their statement for the year ended November 30, 1916, from which the profits are shown to have been 40,398*l.*, after providing excess profits tax, &c.; 20,000*l.* have been put to reserve account, and the dividend and bonus amount to 25 per cent.—At the recent annual meeting, at Abertillery, of the Western Valleys Miners' Council, Mr. George Barker, the agent, referred to the appointment of a Minister of Labour, and said this step would have to be carefully scrutinised by the whole of the trade union movement. If it was an honest attempt by the State to deal justly with the worker, then the Minister of Labour would meet with support from organised Labour, but if, on the other hand, it was intended to make the worker more amenable to pressure coming from high quarters, then the trade union movement would be placed on its mettle. He was prepared to give the Government credit for their *bonâfides* with reference to this matter, and he hoped that Labour, which was all-essential to the welfare of the State, would meet with sympathetic and just treatment from the Government.—At the Anthracite Miners' district meeting, held last Saturday, strong complaints of unemployment were put forward. The agent stated that the average number of days worked in the district was four per week; the reason for this was lack of tonnage, since the orders for the coal were plentiful. The meeting decided to put the matter before the Coal Organisation Committee, and to point out to the committee the allocation of tonnage to ports up channel, preferably to Swansea.

THE LATE MR. JAMES STIRLING.—We regret to record the death on the 12th instant, at Doone, Ashford, Kent, of Mr. James Stirling, formerly locomotive engineer on the South-Eastern Railway and on the Glasgow and South-Western Railway, at the age of 81. Mr. Stirling joined the Institution of Mechanical Engineers in 1880 and the Institution of Civil Engineers in 1886. We hope to give further particulars of his career in a future issue.

GERMAN COAL AND THE SCANDINAVIAN MARKET.—The rise in prices which the Rhenish-Westphalian Coal Syndicate and other German coal and lignite combines have decided upon has been somewhat unfavourably received in Scandinavia, more especially in Sweden. This country, during the last year, has imported two-thirds of her supply of coal from Germany, and the rise in prices is even said to mean an additional outlay in a year of some 2,000,000*l.* It must be remembered that Germany charges special export prices; the increase for Sweden is stated to amount to some 10*s.* to 12*s.* per ton, and for Denmark even a higher figure is mentioned—as much as 17*s.* 6*d.* or more. German shippers informed their Danish customers that all orders for January had been cancelled, and that fresh orders must be sent in.

ENEMY FIRMS IN ALL COUNTRIES.—The Controller of the Foreign Trade Department has issued a consolidating list containing the names of over 2,000 persons and firms with whom persons in the United Kingdom are forbidden to trade under the Trading with the Enemy (Statutory List) Proclamation, 1916. Although the Statutory List has now been in existence for ten months, cases still come to the notice of the Foreign Trade Department in which firms are corresponding with persons on the Statutory List, and they not infrequently give as an excuse that they have never heard of the list. It is important that everyone engaged in foreign trade should realise that he is under an obligation to make himself familiar with the Statutory List and to observe it in his dealings. Failure in this respect renders him liable to the heavy penalties provided by the Trading with the Enemy Acts, and these apply to holding any communication whatever with anybody on the Statutory List, and not merely to entering into an agreement or continuing to carry on business with such persons. In exceptional cases where it appears to be necessary, and where it is not contrary to the public interest, a licence may be obtained from the Foreign Trade Department exempting from the prohibition. The Statutory List is published at intervals in a consolidating form and additions are made approximately at intervals of a fortnight. Copies of the Consolidated Lists and of all additional lists may be obtained at a small cost from the Superintendent of Publications, His Majesty's Stationery Office, Imperial House, Kingsway, W.C. The additional lists are also printed as issued in the *London Gazette* and *The Board of Trade Journal*. Persons engaged in foreign trade should take steps to have access to one of these sources of information.

THE WOOLWORTH BUILDING, NEW YORK.

(*For Description, see Page 47.*)

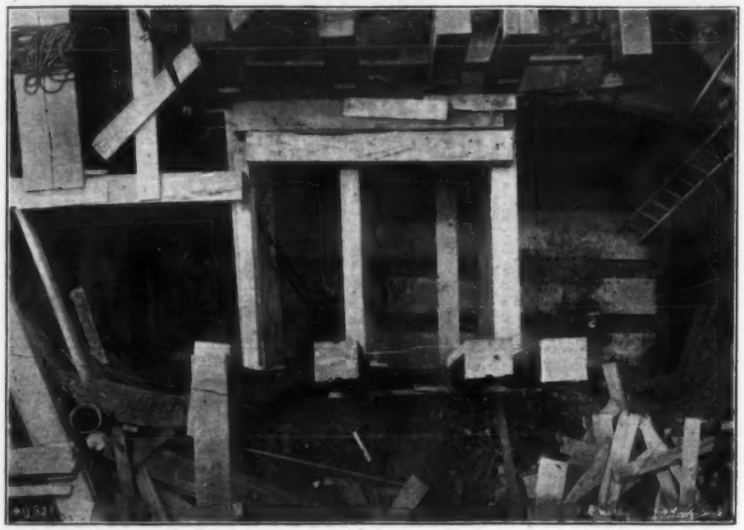


Fig. 8. View of Girders in Place Connecting Piers 41 A and 41 B.

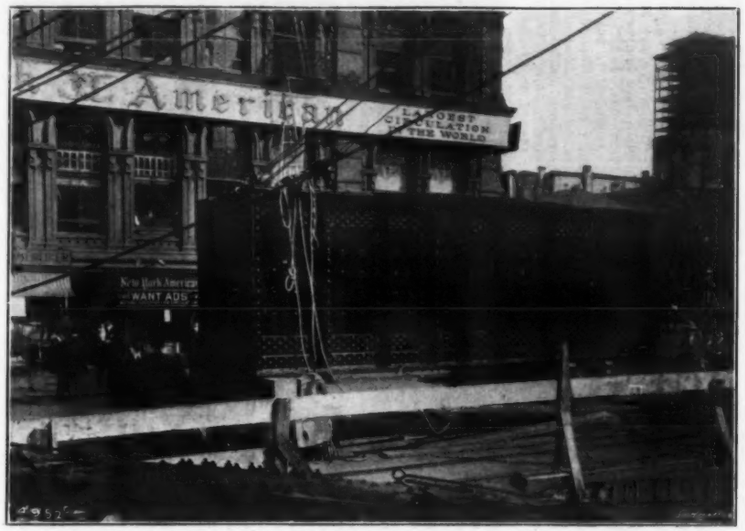


Fig. 10. One of the Foundation Girders.

Fig. 9. View of Cofferdam Protecting Girders for Base of Pneumatic Caisson.

Fig. 11. Air Cushions for Elevators.

THE MOOR-STREET STATION, BIRMINGHAM; GREAT WESTERN RAILWAY.

(*For Description, see Page 50.*)

FIG. 2. THE ISLAND PASSENGER PLATFORM.

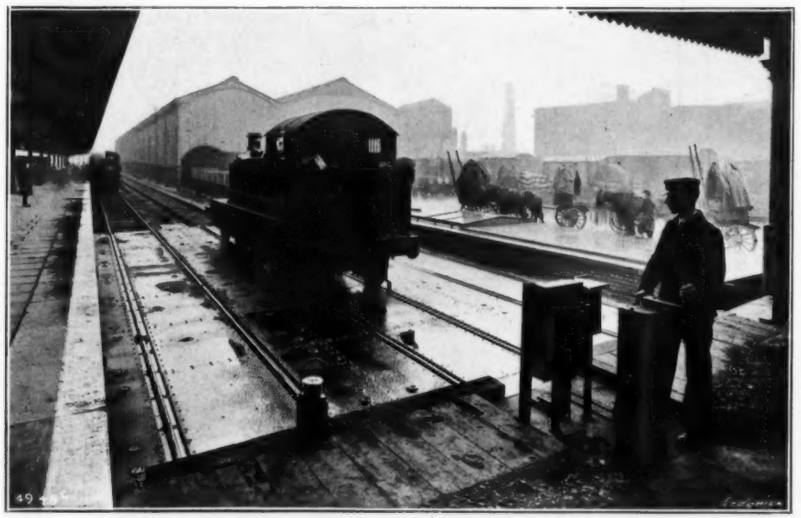
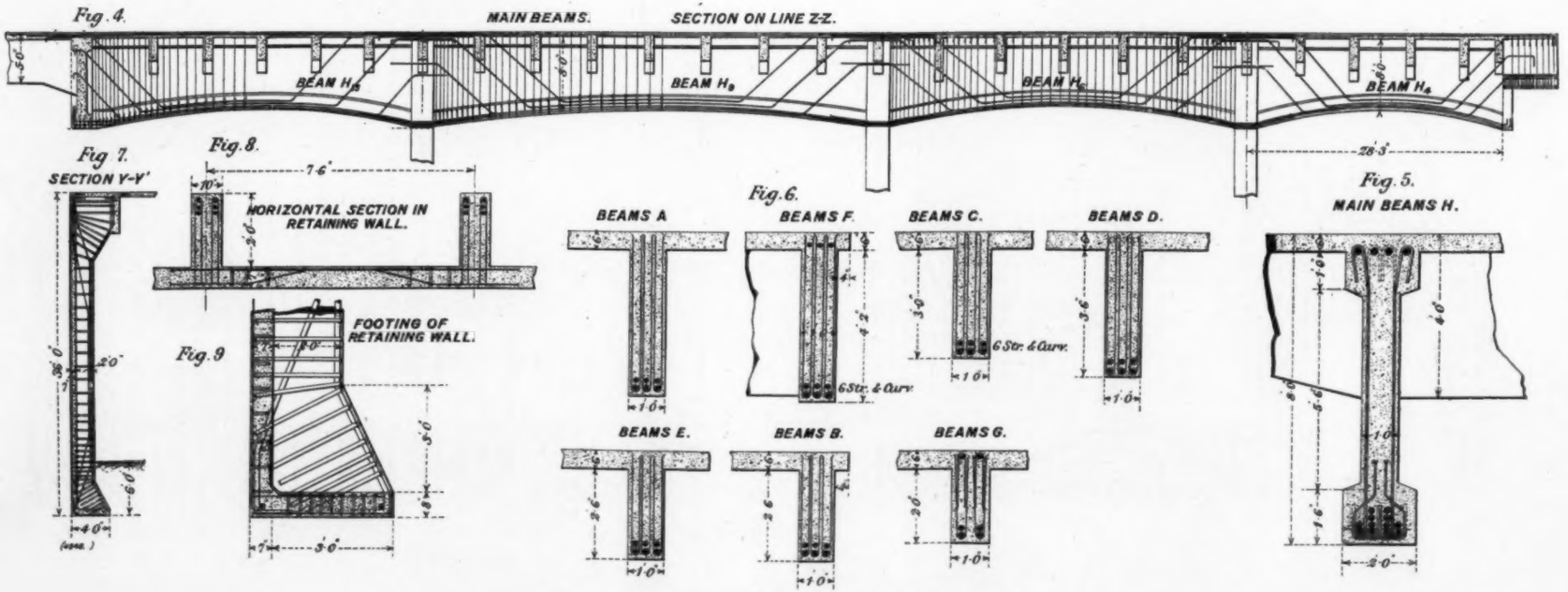


FIG. 3. TRAVERSER.



FIGS. 4 TO 9. DETAILS OF FERRO-CONCRETE CONSTRUCTION.

(*To face page 50.*)

THE MOOR-STREET STATION, BIRMINGHAM; GREAT WESTERN RAILWAY.

(*For Description, see Page 50.*)

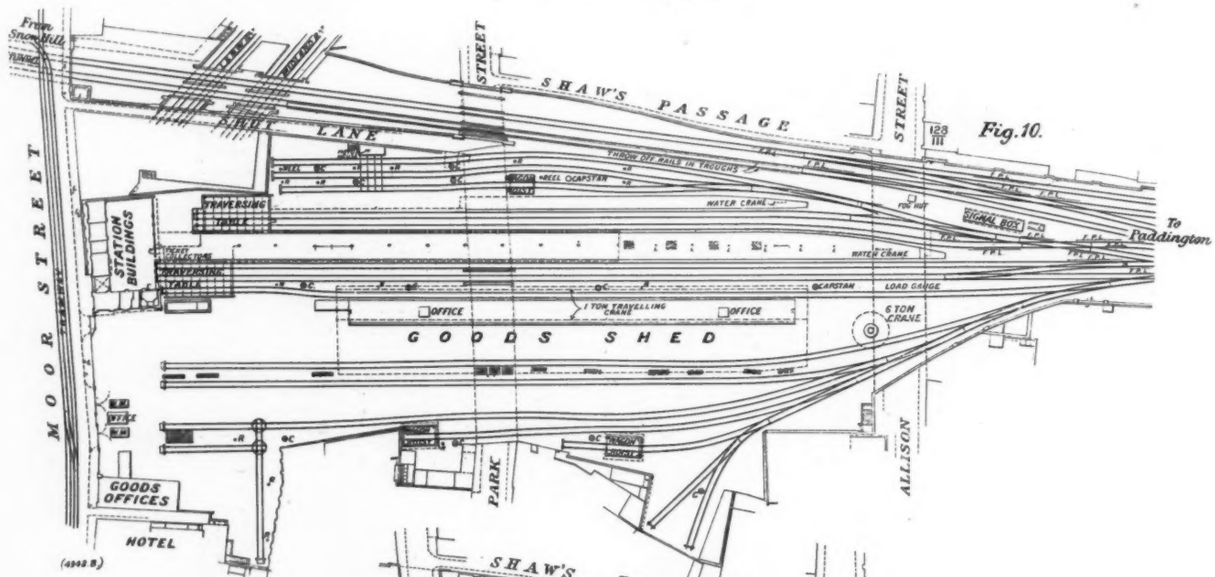


Fig.10.

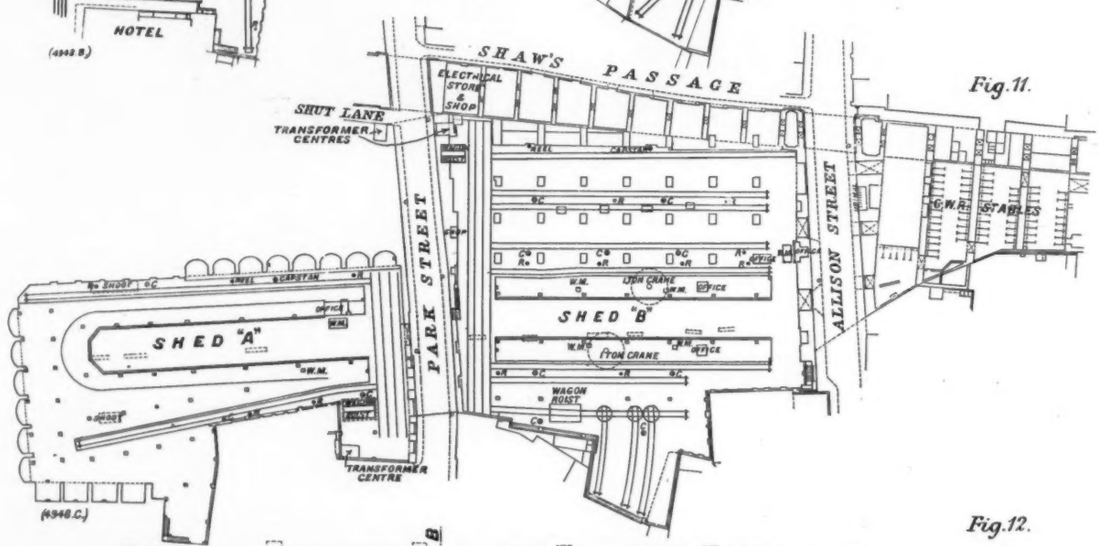
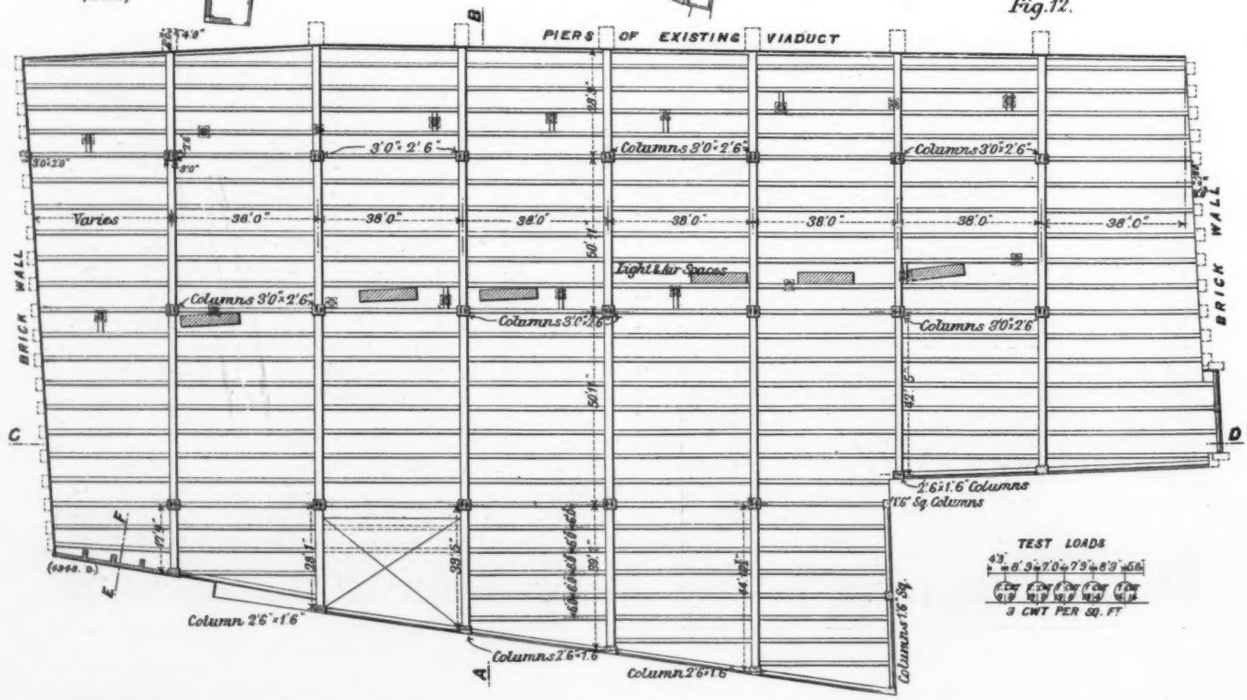


Fig.11.

Fig.12.



THE MOOR-STREET GOODS STATION, BIRMINGHAM; GREAT WESTERN RAILWAY.

(*For Description, see Page 50.*)

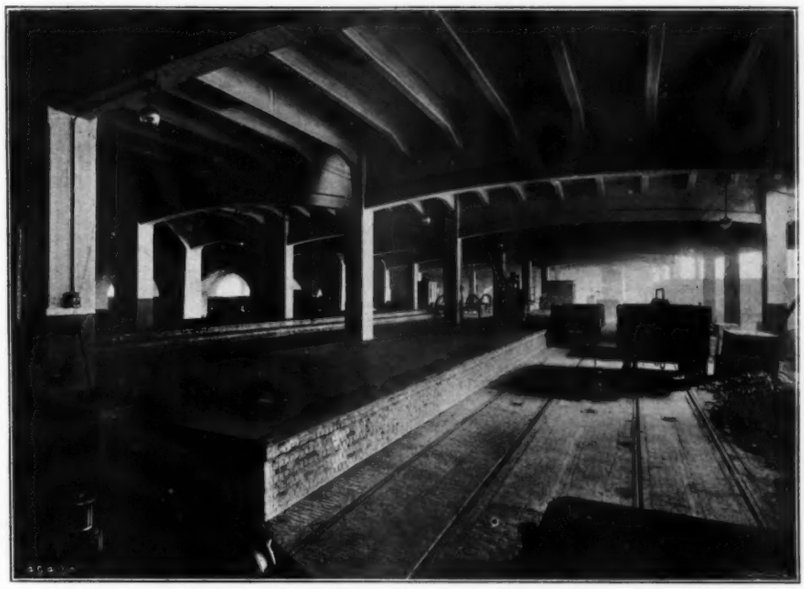


FIG. 13. LOW-LEVEL GOODS SHED.

FIG. 14. THE WORK IN PROGRESS; HIGH-LEVEL GOODS SHED FRAMEWORK.

THE MOOR-STREET GOODS STATION, BIRMINGHAM; GREAT WESTERN RAILWAY.

(*For Description, see Page* 50.)

FIG. 15. HIGH-LEVEL GOODS SHED.

FIG. 16. HIGH-LEVEL GOODS SHED; ONE-TON UNDERHUNG JIB TRAVELLING CRANE.

(*To face page* 51.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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With Four One-Page Plates of the GREAT WESTERN RAILWAY DEVELOPMENTS IN BIRMINGHAM.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 19, at 6 p.m., at the Institution of Civil Engineers. Paper to be read and discussed:—"The Manufacture of Gauges at the London County Council Paddington Technical Institute," by Mr. A. G. Cooke, M.A., Mr. W. J. Gow, and Mr. W. G. Tunnicliffe, Associate Member.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, January 19, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne, when an address will be delivered on "The Resources of the British Empire, their Development, and their Effect on the Industries of the Empire," by Mr. Moreton Frewen, Vice-President of the Imperial Federation League, Member of the Imperial Resources Committee. The ordinary general meeting fixed for January 26 is postponed until February 2.

THE NATIONAL ASSOCIATION OF COLLIERY MANAGERS (MIDLAND BRANCH) AND THE ASSOCIATION OF MINING ELECTRICAL ENGINEERS (NOTTS AND DERBYSHIRE BRANCH).—Saturday, January 20, at 3.30 p.m., at the University College, Nottingham, at a joint meeting of the two branches, Mr. Chris. Jones, A.M.I.E.E., will read a paper on "Electrical Experience at Collieries."

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Saturday, January 20, at the Institute, Wolverhampton Street, Dudley, when Mr. F. J. Cook, Member of Council, will read a paper on "Mechanical Tests for Cast-Iron." The paper will be illustrated by lantern views. Chair to be taken at 7.15 p.m.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 23, at 5.30 p.m. Paper to be submitted for discussion:—"The Physical Features of 'Adam's Bridge,' and the Currents across it, considered as affecting the Proposed Construction of a Railway connecting India with Ceylon," by Mr. Francis John Waring, C.M.G., M.Inst.C.E.

THE ROYAL COLONIAL INSTITUTE.—Tuesday, January 23, at 4 p.m., at the Caxton Hall, Victoria Street, S.W. Paper on "Goods Transport Reform at Home and Overseas" (illustrated), by Mr. A. W. Gattie. Mr. Frederick Dutton will preside.

THE ROYAL SOCIETY OF ARTS.—Wednesday, January 24. A paper on "Relief Work in Belgium" will be read by Mr. W. A. M. Goode, Honorary Secretary, National Committee for Relief in Belgium. The chair will be taken at 4.30 p.m.

THE AERONAUTICAL SOCIETY OF GREAT BRITAIN.—Wednesday, January 24, at 8 p.m., at the Institution of Civil Engineers, Great George Street, Westminster. Lecture by General Brancker, subject:—"The Teaching of Flying."

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—Thursday, January 25, at 3.30 p.m., at the University, Leeds. The paper read at the meeting of the Manchester Geological and Mining Society, on December 19, on "Fuel Economy, with special reference to Briquetting," by Mr. Lantsberry and Mr. Paton, will be discussed. Mr. Walter Newton Drew will read a paper on "The Rectification of Benzol."

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, January 26, at 5.30 p.m. A discourse will be delivered by Professor Gilbert Murray, M.A., LL.D., Litt.D., F.B.A. The subject is "Epicurean Philosophy." Afternoon lectures next week at 3 p.m. Tuesday, January 23. Professor Charles S. Sherrington, M.D., LL.D., D.Sc., F.R.S., Fullerian Professor of Physiology, R.I., on "The Old Brain and the New Brain, and their Meaning" (Lecture II). Thursday, January 25. Professor Sir Walter Raleigh, M.A., Professor of English Literature, Oxford, on "The Strength and Weakness of Romantic Poetry" (Lecture II). Saturday, January 27, Mr. Arthur R. Hinks, M.A., F.R.S., on "The Lakes and Mountains of Central Africa" (Lecture II).

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—Saturday, January 27, at 2.30 p.m., the annual general meeting will be held at Caxton Hall, Westminster. A presidential address will be delivered by Mr. A. D. Jones, M.I.Mech.E., Outdoor Locomotive Superintendent, South-Eastern and Chatham Railway.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, JANUARY 19, 1917.

DEPRECIATION.

FOR the first time in the history of manufacture the works manager views the item of depreciation with a favourable eye. Hitherto it has been like a poor relation, something that could not be disowned or disregarded, but must be bought off as cheaply as possible. When profits were favourable the beautiful rotundity of their proportions was pared down by the demands of depreciation, and when they were small they were rendered still more exiguous by its claims. It was only when profits disappeared that the manager could snap his fingers at the accountant and omit the item altogether, unless his principal or his directors were too punctilious to allow of this. Generally directors, who had to face the shareholders, were even less anxious than the manager to swell the adverse balance. The war and the excess profits tax have quite altered this state of affairs. In the first place, the percentage fairly debitable to depreciation has increased very greatly, since the 48 or 52 hours which formerly constituted a week have risen in some cases to 168, and in many cases to 130 or 140. This means multiplying the ordinary depreciation by 2½ to 3½. But this is really the smallest part in the factor of increase. The policy of ca' canny had, at least, the advantage that it did not wear out the tools very much, but that has now been succeeded by piecework of a most energetic description. Men think more of getting the work out than of caring for their machines, even when they are trained mechanics. Most of the new workers, however, are not mechanics of any kind; they are destitute of the instinct which tells a man how tightly a nut may be screwed up without damage to the thread, and which recognises when a thrust bearing is loaded beyond its capacity. They act as if there were no limits to the strength and endurance of steel and iron, and are quite oblivious to the groans and squeals of a lathe taxed beyond its capacity. Under the new conditions depreciation grows from a modest 5 or 7 per cent. to something more like 30 or 40, and unless this is kept in mind by manufacturers, and admitted by the Inland Revenue, the large profits we hear of may prove to be illusory. Of course the Government gets the benefit, and there are no limits to its necessities, but we have also to think of the time after the war, when engineers will need large sums to rearrange their works and to buy new and more complicated machines to meet the competition both of our enemies and of neutrals. If depreciation is calculated on too restricted a basis, it may easily be found that money has been paid away in profits and taxes which ought to have been retained for the future. It is to be hoped that the Inland Revenue will avail itself of expert advice in this matter. Hitherto it has endeavoured to squeeze the last shilling out of the taxpayer, so much so that far-seeing companies will often pay income tax on a larger sum than they distribute in dividends, because they feel that the amount allowed them for depreciation will not cover wear and tear and the risks of obsolescence. The latter element, which, of course, is largely speculative, does not affect munition-making machines, which wear out too rapidly ever to become antiquated. The risk in their case is that their owners will find that the demand for the products of the machines has vanished, and that the tools will become valueless because their occupation has gone. In regard to many of the special machines for shell-making which have been introduced during the past eighteen months, this is not a matter of speculation but of certainty. These are designed for a single purpose, and that purpose will disappear with peace. No doubt there will be other wars in years to come, but before that time the machines will be obsolete. They need to be written off completely.

Depreciation is not a new subject; it has demanded consideration ever since there have been organised manufactures. Yet it is strange that there are still divergent ideas to the way in which it should be charged—quite apart from the percentage—and that there is no recognised practice. The cause, of course, is that the method matters little so long as enough is set aside. The money stays in the concern, and it is not of great importance whether it is represented in the accounts in a way that is scientifically accurate. But of late years a new element has arisen by the terms laid down by the Legislature defining the powers allotted to companies desirous to supply "public utilities," such as telephones, tramways and electric light. It has become the practice to stipulate that these shall be subject to pre-emption after a certain number of years at a price representing the value of the plant. But it is by no means easy to fix the value of a machine for which there are no competing buyers, and valuers, when called upon to defend their estimates, usually fall back upon some system of making deductions for depreciation based upon an assumed length of life. Some sixteen years hence there will be several million pounds' worth of electric light plant in London liable to pre-emption by the municipal authorities, and hence the subject of depreciation is becoming one of great interest to electrical engineers. Their accounts are published annually, and it would be difficult to argue that the plant was worth more than their own figures showed. What is the right way and what is the wrong way of making deductions formed the subject of a paper read before the Institution of Electrical Engineers, in London, on the 18th inst., by

Mr. F. Gill and Mr. W. W. Cook. Of course, the views of the authors apply beyond the confines of electric light companies, and are of interest to all manufacturers who desire to keep their accounts scientifically.

There are four recognised methods of charging depreciation:—(1) The reducing-balance method; (2) the straight-line method; (3) the annuity method; and (4) the sinking-fund method. The first consists in writing-off a percentage each year of the reduced value of the machine. The authors exemplified each system by its application to a hypothetical machine costing 100*l.* and having a physical life of 25 years, with a scrap value of 2*l.*, and an economic life of 19 years, with a scrap value of 13*l.* They showed the result both in diagrams and tables. It is assumed that the 100*l.* should provide 5*l.* annually for the shareholders, and that enough should be written off to provide 87*l.* at the end of 19 years.

In the first method—the reducing-balance method—a fixed percentage is charged each year against the last year's value, and consequently the value of the machine shrinks, while the sum in the depreciation fund increases by a like amount. For instance, the capital value of the machine in question becomes in successive years, at 10.182 per cent. depreciation, 100*l.*, 89.82*l.*, 72.46*l.*, 65.08*l.*, and so on, while the depreciation fund is represented by 0*l.*, 10.18*l.*, 19.33*l.*, 27.44*l.*, 34.92*l.*, and so on. There is always 100*l.*, made up of machine value and money in the fund, to earn the 5*l.* dividend, and at the end of 19 years the machine is worth 13*l.* and the fund 87*l.* It will be noted that the interest of the fund is paid to the shareholder, and is not credited to the fund. Further, the value of the machine falls very rapidly at first (10.18*l.* the first year), and very slowly towards the end (2.19*l.* the last year), the curve getting gradually flatter. Now this does not agree with the facts. A machine, properly cared for, suffers no damage the first three or four years. A steam engine may actually increase in efficiency during that time. Some kind of plant is like the elder's "one-horse shay"—it runs efficiently to the last and then collapses. This is the case with a good deal of electric plant. A telephone pole will carry its wires with uniform efficiency until it is blown down or condemned by the inspector, and an underground conduit suffers little decay, if any. On the other hand, a machine goes from bad to worse very fast towards the end, and its earning capacity may decrease even faster, quite apart from obsolescence, to which we shall refer later. The praiseworthy feature of the reducing-balance system, when applied to machine tools, is that it acknowledges that the earning power of moving plant suffers a steady diminution. It even emphasises this more at the beginning, but that is just the time when the machine can earn big profits, and it is sound policy to take advantage of this ability, even if it be not scientific book-keeping. In plant that does not deteriorate gradually, but all at once, the value fixed by the first method is very far remote from the facts.

The straight-line method is distinguished by its simplicity. Under the hypothetical conditions 5*l.* is required annually for interest and 4.58*l.* for depreciation fund, the latter totalling 87.02*l.* in 19 years, without interest. The 5*l.* goes to the shareholder, and the 4.58*l.* is invested, either in a special fund or in the business. The interest of the fund, however, goes into the general account. The machine is supposed to earn its 5*l.* a year all its life, and the dividend is swelled by interest from the depreciation fund. If the interest be added to the depreciation fund year by year, then a depreciation of 2.85 per cent. would be sufficient to furnish 87*l.* in 19 years. In the case of plant like the telephone pole it is clear that the dividends are by the straight-line method, being reduced in the early years and augmented in the later years, while the profits are uniform. Clearly this is not good book-keeping. In the case of machine tools the interest from the depreciation fund is available to supplement the reduced earning capacity of the tools, and the only difference between the first system and the second is that in the second the reduction of value is assumed to be uniform and not decreasing. Both systems look to the interest of the depreciation fund to supplement the decreased earning capacity of the plant. In the last year, under the straight-line system, the interest amounts to 4.12*l.* per cent. on the 100*l.*

The third system is the annuity method, by which each year a part of the capital is repaid, and a return is paid on the capital outstanding. The total annual charge is uniform at 7.85*l.* for interest and depreciation, and is made up of a decreasing return component and an increasing depreciation component. In the course of the 19 years the amount available for depreciation rises from 2.85*l.* to 6.86*l.* The capital value is written down each year by the amount of the depreciation, and consequently the amount required for interest grows less and less. At the same time the interest earned by the depreciation fund is paid into the general account, so that the shareholder still gets his 5*l.*, partly by earn,ng from the depreciated machine and partly from the fund. By this plan the plant is written down slowly at first, and more quickly towards the last, which certainly corresponds with the condition of moving machinery.

The fourth method is the sinking fund. The total annual charge is 7.85*l.*, made up of uniform charges each year, both for interest and depreciation. The interest earned by the fund is added to it annually, while the value of the plant is not written down, but is credited with earning 5 per cent. all the period. This is exactly the case of the telephone pole. It will be observed that the amount set aside in methods (3) and (4) is identical, and the result is identical at the end of 19 years. The difference is that in one case the value of the plant is supposed to decrease annually and in the other it remains constant. The difference is one of book-keeping mainly. Method (3) certainly has advantages over (1) and (2), from the point of view of the man who is liable to be pre-empted, for it does not oblige him to admit that his plant ages faster than the years go by, or even as fast. It involves, however, the assumption, as do methods (1) and (4), that 5 per cent. can be earned by the depreciation fund, either in the business or outside it, for 19 years. If there were any falling-off in this respect the consequence would be serious, as it is in the latter years that the compound interest mounts up. The manufacturer who adopts method (1) and accumulates money fast in the early years is in the safer position, while the one following the straight-line method (2) is not dependent on the interest of the fund to square his accounts. It is just a gift from the gods.

Nothing has been said about obsolescence, because that is entirely a different matter from depreciation. If it be conceded that it is possible to foretell the life of a plant, then depreciation is merely a matter of book-keeping. But obsolescence is a risk, and, like all other risks, must be covered by insurance. The invention of a new machine or process—by someone else—may be as disastrous as a fire, and is far more likely to occur. Long experience has enabled the actuary to estimate many risks, such as fire, shipwreck and sickness, but we have no certain figures about obsolescence. One fact, however, is certain, that the risk grows greater every year, and therefore the necessity of insuring against it. Unfortunately there are no insurance companies dealing in this class of business, and therefore each manufacturer must create a fund for himself. It is a matter for his judgment to decide what the premium shall be, but it is well to err on the safe side, for even if there be no striking invention the trend is towards more elaborate and more expensive machines. Our hypothetical 100*l.* may be forthcoming at the end of 19 years, but it may be found that the new machine costs 200*l.* It is perfectly legitimate to raise new capital for the purpose, but it is not always easy. Very often reconstruction is forced on a concern by diminishing dividends, and a succession of these is a poor recommendation to the investor. A big reserve fund is a most useful asset, but, like many other desirable things, it is difficult of attainment, especially by limited companies, whose shareholders generally think more of present dividends than of future safety.

Methods of providing for depreciation and obsolescence depending upon the growing power of compound interest do not concern munitions makers just now. If the life of a machine be estimated at two years, any one of the four methods detailed above is as good as another. The point of critical interest is whether the life will be 18 months, two years or three years. A mistake in this respect will be of far greater importance than the selection of a straight-line diagram in place of a curved one. In case of dispute a straight line appeals to the non-technical man. As a speaker said in the discussion of the paper under notice, the seller says the curve with the rounded side upwards is the right one; the buyer says the curve rounded downwards gives the proper result, and the arbitrator draws a straight line between them and bases his award on that.

LABOUR TROUBLES AND STATE INTERVENTION.

AT a moment when so many proposals for the reconciliation of Labour and Capital after the war are being discussed, and particularly in view of movements for bringing industry, and especially industrial disputes, under Government control, it may not be inappropriate to sound a note of warning against too much State intervention. Those people who are advocating the appointment of Statutory Boards, for instance, or favouring anything calculated to lead to compulsory arbitration, may advisedly be reminded that the more State interference we have had in labour disputes—the more Government "machinery" we have had for avoiding, or settling, strikes—the more frequent, big and costly have strikes become. This is a circumstance to which special attention should be directed, for it is a real case of cause and effect, and not a mere coincidence. The way to industrial peace is through goodwill; but when the State, or the law of the State, or the official of the State, comes in too frequently between man and man, or between class and class, or between association and association, goodwill goes out. Since the Government has shown itself increasingly disposed to step in between workmen and employers and settle disputes by legislation or arbitration—since we have had the appointment of State labour advisers and conciliators and industrial councils, and so forth—we have had a serious growth of discontent, disputes, and the breaking of agreements.

It is very easy, and it seems very plausible, to argue that because the nation or community suffers through strikes, the Government, as guardian of the public interests, should have a special right to take measures to avoid or settle industrial disputes. But the policy of State intervention, in actual practice, defeats its own object. And for these reasons: It encourages the extremists on both sides to stand out to the last for unjustifiable terms; it places the moderate men in difficulties; it takes responsibility from the parties negotiating, or engaged in disputes; it stimulates the breaking of agreements; and it creates resentment and bitterness.

It may be recalled, at this point, that for some considerable time, down to about ten or a dozen years ago, strikes were diminishing. Employers were coming more and more to understand Trade Unionism and to respect union leaders. The members of the unions were becoming more and more loyal to their leaders. Conciliation Boards—*voluntary* Boards, be it observed—were established in most of the big industries and in some small ones. Wages, profits, and selling prices were in process of being harmonised. Labour was getting a stronger and stronger voice in the control of industrial conditions. Agreements made between the employers and the trade union representatives were generally honoured, and there was a pronounced movement towards industrial peace. Through the agency of voluntary conciliation strikes were steadily decreasing.

But about 10 or 12 years ago progress was arrested and retrogression set in. Strikes began to increase, and have gone on increasing, ignoring, of course, the abnormal war period. More time was lost by strikes and lock-outs in the last 10 years before the war than in the previous 30 years. This deplorable state of affairs has synchronised with the increasing activities of the Government in the direction of settling disputes! There need be no mystery about this. The trouble is no more than

the natural and inevitable corollary of the policy of State intervention. This intervention takes responsibility away from the parties primarily interested in labour disputes and encourages the small minority of hotheads and mischief-makers on both sides. If the Government made it a fixed policy to keep out of labour disputes, save in the most special and extreme cases, the negotiators on both sides would be left with the full and final responsibility of settling their differences and making and observing agreements. In such circumstances the extremists could not hope to gain anything by advancing extravagant demands or withholding reasonable concessions, as the case might be. Credit or blame for the good or ill that came of disputes, or their settlement, would invariably go to the right parties, and in that knowledge there would be a strong and determining disposition on both sides to compose differences, arrive at practical agreements, and honour bargains.

But since it has come to be known that the State, or some State Department, is quite prepared and willing to step in between the disputing parties and arbitrate, or even pass a special Act of Parliament to settle the trouble, see what happens. The extremists on both sides simply gamble on the Government award giving them something more than they can secure by voluntary negotiation. It is becoming more and more common for the one side to make unreasonable demands and for the other side to withhold reasonable concessions. Responsibility is destroyed. Both sides know that if they fail to settle voluntarily, if the negotiations are unduly protracted, and if the worst comes to the worst—if a strike occurs—the Government will step in and make an award somewhere about midway between the respective terms demanded and offered. Besides, this policy affords the most wanton transgressors a ready escape from untenable positions. If a demand, or a movement, succeeds, the originators of it claim full credit. If it fails, they blame the Government, or the arbitrator. If the Government kept out of these disputes they would very seldom develop into crises. Both sides would make genuine efforts to settle in a reasonable spirit. Moreover, agreements made voluntarily are invariably observed faithfully in spirit as well as letter. But on one side or the other there is nearly always a strong disposition to "get round" agreements enforced by the State or by a statutory arbitrator, with the result that bitterness or friction follows. The way to industrial peace is through voluntary conciliation and goodwill, coupled with a more thorough understanding on both sides of labour and trade economics, as previously suggested in these pages.

PETROLEUM IN ENGLAND.

THE announcement of a paper on "The Occurrence of Petroleum in England" may remind the reader of the traditional chapter on "Snakes in Ireland" in some natural history of Ireland. "There are no snakes in Ireland," that chapter is said to read. "There is no petroleum in England," people will say, and, broadly speaking, they are right so far. Yet there is sufficient justification for bringing the "Occurrence of Petroleum in England" before the Institution of Petroleum Technologists. This was done last Tuesday by Mr. William Forbes-Leslie, M.B., F.G.S., of Eastbourne. Mr. Forbes-Leslie was not in a position to announce—even with the reserve which the present political aspect might exact—the opening of powerful petroleum wells in this country. But dealing scientifically, for the first time probably, with the possibility of economic petroleum deposits in this country, he could marshal up strong evidence for the preservation of free oil in large quantities in certain localities, and for the "suspicious" juxtaposition of those deposits to tectonic underground structures capable of detaining such free oil. His evidence, it will be understood, is essentially historical and geological. Finds of free petroleum have been reported from time to time from many parts of the country; but they all had their day, the flows did not last long. The oil-shales of commercial value that are being worked are mostly situated in the north of Britain; Mr. Forbes-Leslie finds in the south and east indications in vast quantities of oil-shales, overshadowing those being exploited. The oil, he suggests, is probably in the Carboniferous, not in the Jurassic, and at considerable, though not by any means prohibitive, depths. Wherever the folding in the Carboniferous led to the development of good anticlines, and where the suitable materials were present, he argued, there oil might be expected—he spoke cautiously of a suspicion—and the frequently observed escapes of petroleum certainly support him. Yet his paper was in a sense revolutionary, as Mr. Cunningham-Craig put it; and it cannot be said that the many pages of tectonic geology through which Mr. Leslie hurriedly took his audience, without the aid of a map, though the explanations presumed a very intimate knowledge of geographical detail, were very instructive to his listeners. The map is to be added, and the paper can then be studied with the care it seems to deserve.

Discoursing on Geological Mapping four weeks ago, before the same Institute, Mr. Lister James had insisted that a proper geological survey should be made before erecting any derricks, and Dr. Strahan, Director of the Geological Survey, last winter, in the Royal Institution, regretted that much valuable geological evidence which might be collected, and was collected, during commercial prospecting for minerals was entirely lost to science and to the country. With more abundant and reliable data at his disposal, Mr. Leslie's task might have been easier. He pointed out that petroleum was first struck in the Eastern United States within the limits of the Silurian and Lower Devonian. The Tertiary of our country did not appear to contain liquid oil. The bituminous shales, from which oil could be obtained by artificial means, were in the lower divisions of the Upper Oolites, and, with a possible exception of Liassic oil near Bristol, no real oil zone seemed to have been reached before the Carboniferous was encountered. The actual oil escapes in Norfolk (on the line from King's Lynn to Ely) and elsewhere were on the surface of Jurassic rock, but probably of Carboniferous or earlier origin. To investigate this problem the position of Britain in the geological record had to be examined in connection with the geology of the Continent, of which the British Isles once formed part, and from which they were separated by the Channel and the North Sea, the latter nowhere more than 95 ft. in depth. Great Britain stood on a broad Continental border, over which the depth of the sea did not exceed 600 ft.

Having followed, as we have mentioned already, the axial lines, folds, anticlines, synclines, and faults, which the action of tectonic uplifting and depressing forces, thrust and other factors had produced in England and Wales, in detail over the country, especially over the eastern Midlands, Mr. Forbes-Leslie traced the recorded occurrences of seepages (oil leakages) to tectonic features, to the meeting of anticlines, and to faults. Those occurrences were more frequent in the middle and eastern zones than in the northern zones. The founder of the Scottish shale industry, Dr. James Young, 70 years ago, manufactured paraffin wax from oil flowing from the Reddings Colliery at Alfreton, in Derbyshire; for a year or more up to 70 barrels of oil had been gained weekly and been sent up to the refinery in the north which Young had started. Minor discharges were recorded from many other spots. Within quite recent years a most remarkable oil find had been made at Kelham, near Newark, where, at 2,452 ft.—Mr. Leslie afterwards gave the exact depth as 2,439 ft. 2½ in.—13 ft. of a grey sand had been struck, below the millstone grit, from which oil had forced its way up for 11 months through the high column of water in the hole. We do not quite understand why this coming-up of an oil lighter than water should be considered remarkable. This statement was subsequently confirmed by Mr. J. Ford, who had made the boring, and who added that the boring had been stopped when they got into the limestone underneath that sand. Mr. W. H. Dalton suggested during the discussion that at Kelham the fault had itself been struck. Mr. Leslie thought that those oil sands were merely the upper sands of a productive series of unknown thickness. In any case the occurrence seemed to be one of those connected with the three anticlines of the eastern depression of England, the Ashover–Sherwood–Kelham anticline, the Castletown–Retford anticline and the Ouse valley fold. The latter, the Ouse valley fold, or King's Lynn–Downham anticline, was likewise very important; the escapes occurring there had, by others, been ascribed to other sources before Mr. Leslie had traced that fold. Those Norfolk deposits of oil-shale, containing probably 30 or 40 gallons of oil per ton, 75 per cent. of this being in the form of free oil, seemed to amount to hundreds of thousands or millions of tons, and enormous bulks of petroleum were apparently absorbed in those strata. The shale-oil was, as just indicated, of a dual character, the greater part being free oil, not requiring any temperature above 350 deg. F. for its extraction. We see that Mr. Leslie ascribes, with Mr. Cunningham-Craig, a common origin to shale-oil and to free oil, a question into which he did not enter, however. Nor did he, we should mention, dwell upon the intermittent character of all the British oil flows recorded.

The lecturer referred to many other oil seepages, at Brigg, in Lincs. (where the oil apparently comes from the Kimmeridge shale); at Donnington (Lincs.), in the Middleton – Flamborough Head fold; at Middlesbrough, and other places. He attached most importance to the occurrences in north-west Norfolk, where the first oil sands should be found at depths between 2,500 and 3,000 ft. There would probably be coal measures as well there. He dealt in particular with the eastern depression, as most interesting, and has not yet attempted apparently to trace the historical oil occurrences at Whitehaven, in the Wigan district, at Swinton, in Staffordshire, Shropshire and near Barnstaple in the same way. It remains to be seen whether other geologists will support Mr. Forbes-Leslie in his conclusions; Mr. Cunningham-Craig and Dr. Henderson agreed to a certain extent. All geologists will, however, welcome further drilling and further research. Deep boring will be required for this as for other reasons. Let us hope that it will be successful.

NOTE.

DURABILITY OF STUCCO AND PLASTER.

EXHIBITIONS have made the public familiar with stucco buildings, and the stucco villa enjoys a certain popularity in the suburban districts of many cities. That is so in America as well as in Europe, and the development has been so rapid that little opportunity has so far been found or been taken to observe and test the suitability of methods and materials, though the experience of stucco has not by any means always been satisfactory. In conjunction with the Associated Metal Lath Manufacturers the United States Bureau of Standards undertook, in 1911, exposure tests of metal laths plastered with various materials, mainly for the purpose of determining the best methods of construction to insure the protection of the metal from corrosion. These tests, which are still in progress, proved that painted or preferably galvanised lath, embedded in dense, water-resisting plastering material, would not corrode. At the same time, some plastering materials were in themselves found defective, of course, and the manufacturers of lime, cement, gypsum, hollow tiles, metal laths, &c., suggested a conference of interested parties. As a result a committee was appointed in 1914, consisting of members of the Bureau, of representatives of the Supervising Architect's Office of the Treasury, of the American Concrete Institute, of the industries and, further, of three experienced contracting plasterers. A test structure, 200 ft. long, 26 ft. wide and 24 ft. high, was erected in the Bureau grounds, and 56 stucco panels, each about 15 by 10 ft., were prepared, the building serving for the exposure of the panels and for the erection of plaster walls and partitions. When the panels were examined, in April, 1916, after six months' exposure, only two panels were found entirely free of cracks; 40 per cent. of the panels were considered satisfactory, but the majority were more or less deteriorated. The tests were rather discouraging, therefore; but it must be stated that in the panels a smooth type of finish, commercially known as "sand float finish," had been employed, which is more likely than the usual rough type of finish adopted by builders to bring out any superficial defects. The report contained in Technologic

Paper No. 70, which was drawn up by Messrs. R. J. Wilg, J. C. Pearson and W. E. Emley, does not draw any general conclusions, in view of the necessity of further experimental work. No recommendations are offered for stucco construction. The forms and construction of the stucco specimens examined and their present condition are described, however, and it is intended to issue a further report dealing in particular also with various stucco structures which have been standing for five or more years.

MUNRO'S MARINE ENGINEERS' ANNUAL.—This interesting publication, with which is incorporated "Donaldson's Engineers' Annual," is published at the price of 1s. net by Messrs. James Munro and Co., Glasgow. As its title implies, it is compiled for the use of marine engineers, who, we feel sure, will give it a cordial welcome. But, quite apart from the marine engineering profession, engineers in general, and also the staff in works offices, will find it a handy book of reference.

"REGISTRATION OF BUSINESS NAMES" BILL.—The following are the amendments put forward by the Wholesale Traders' Association, and now included in the Bill as passed:—(1) The addition of the true names of the owners of the business on all trade catalogues, circulars and business letters. (2) Disclosure of nationality. (3) The exhibition in a conspicuous position in the principal place of business of the certificate of registration. (4) A legal representative or a trustee of a will or a trustee for creditors or other persons to be required to register. (5) Responsibility to be placed on persons and firms to register, and increased penalties in default.

COMMERCIAL INTELLIGENCE COMMITTEE.—A meeting of the Advisory Committee to the Board of Trade on Commercial Intelligence was held at 7, Whitehall-gardens, on Wednesday the 10th inst. Sir Albert Stanley, President of the Board of Trade, occupied the chair. At the commencement of the proceedings the President of the Board of Trade briefly addressed the committee, and emphasised the importance of its work. Amongst the matters considered by the committee were proposals for a large extension of the Trade Commissioner Service in the British Dominions, proposals for commercial missions, and other matters relating to the organisation of British overseas trade, and questions arising out of the work of the Department of Commercial Intelligence.

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE.—An important course of public lectures has been arranged by the London School of Economics and Political Science (University of London) on "The Staple Trades of the Empire" in furtherance of the aims of the Imperial Studies Committee of the University of London. On Friday, February 2, at 5 p.m., Mr. Arthur Steel-Maitland, M.P., Under-Secretary of State for the Colonies, will open the course with a lecture on "Oils and Fats in the British Empire," at which the Right Hon. John Hodge, M.P., Minister of Labour, will take the chair. The subsequent lectures will be as follow:—February 9, at 5 p.m., "Metals as the Base of Imperial Strength," by Mr. Octavius Charles Beale, chairman of the Chamber of Commerce, Sydney, N.S.W.; February 16, at 5 p.m., "The Cotton Resources of the Empire," by Professor John A. Todd; February 23, at 5 p.m., "The Importance of Imperial Wool," by Mr. Eldred F. Hitchcock, of the Raw Materials Branch, War Office, when the Prime Minister of New Zealand will take the chair; March 2, at 8 p.m., "The Wheat Supply of Great Britain," by Mr. Hugh Rathbone, with Sir Henry Rew, K.C.B., in the chair. Tickets for the course may be obtained free of charge on application to the Secretary, London School of Economics, Clare Market, W.C.

THE AERONAUTICAL SOCIETY OF GREAT BRITAIN AND THE SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS.—An agreement likely to have far-reaching effects upon the development of aeronautics has lately been entered into between the Aeronautical Society of Great Britain and the Society of British Aircraft Constructors, as the result of conferences between the two bodies. The main objects of the agreement are to provide for the co-operation and mutual support of the two bodies in their respective spheres, to develop and co-ordinate aeronautical research, and, generally, to link up the scientific and industrial aspects of aeronautics. Under the agreement in question the Aeronautical Society of Great Britain is recognised as the paramount and representative body of the scientific and technological aspects of aeronautics, while the Society of British Aircraft Constructors is recognised as the paramount and representative body of the British aircraft industry. The aircraft engine is, of course, covered by these provisions. All questions relating to scientific and technological research arising from the mutual action of the two societies shall be dealt with by the Aeronautical Society, and, similarly, all industrial questions shall be dealt with by the Society of British Aircraft Constructors. The Government proposals for the development of scientific and industrial research will have an important bearing on the working out of the arrangement. The arrangement to which the Aeronautical Society and the Society of British Aircraft Constructors have come entirely agrees in principle with the purpose of the new Government department, and industrial and scientific research in aeronautics cannot fail to be substantially advanced thereby.

THE OPTICAL SOCIETY'S EXHIBITION.

THE Physical Society's exhibitions of scientific apparatus, which had become most popular and useful gatherings of scientists and of makers of scientific instruments, were discontinued when the war broke out. On these occasions optical science had always been well represented, and as times are not propitious for another optical conference, and the demand for optical appliances has grown enormously, it is not surprising that all people interested in optics should have welcomed the suggestion of an "Exhibition of Workshop Methods of Testing." The initiative, we understand, is due to the Ministry of Munitions and to Mr. F. J. Cheshire, president of the Optical Society and in charge of the Optical Department of the Ministry of Munitions. The exhibition was held in King's College, on Thursday, January 11, between the hours 5 and 9.30 p.m.; the rooms were overcrowded all the time. There were more novelties shown than might be expected. The great variety of devices used by different workers for the same purpose is not easily explained in a few lines, of course. We follow, in our notice, the alphabetical arrangement of the guide.

Messrs. T. H. Ball, of 76, Newman-street, W., showed a simple testing apparatus for signalling mirrors. The mirror is placed horizontally on a table turned by hand; above the table is an illuminated screen, on which straight and circular lines are marked; a good mirror shows the reflection of these lines single and regular, a poor mirror gives double (from the front and the back of the mirror) and distorted lines.

The Cambridge Scientific Instrument Company exhibited a screw-measuring machine for the accurate determination of the various elements of screw threads, and a simple but accurate workshop measuring microscope, provided with a goniometer eyepiece; apparatus of theirs were to be seen on other stands.

Mr. S. D. Chalmers, of the Northampton Institute, Clerkenwell, had several novelties on view which he had recently brought before the Optical Society. His measuring microscope for determining the curvature of short radius of grinding tools, test plates, &c., carries a special target consisting of two parallel black lines, about 200 mm. apart; first the one and then the other line is sharply focused, and the lens is adjusted until the line becomes central in the field. In an apparatus for measuring the difference of curvature of pairs of test plates and determining the curvature of almost flat plates (radius above 500 mm.) by means of sodium light rings (yellow), the test plate is so placed on a plane plate that the point of contact is on the axis of the microscope, which is then focused on the system of interference rings, and the diameters of some rings are measured; the first, eighteenth and thirty-seventh are generally selected for simplifying the calculations. It is convenient with this arrangement to move the microscope itself (in the horizontal direction) rather than the stage, lest the lens prisms should rock on one another. The use of apparatus for measuring prism angles (according to Chalmers and H. S. Ryland) and the pyramidal error were also demonstrated; a pyramidal error arises in a prism when a face is not exactly parallel to an opposite edge.

Messrs. Chance Brothers demonstrated the use of a mica wave plate (consisting of several laminæ of mica cemented between glass plates) for the approximate assessment of double refraction in glass in the way that weak double refraction is detected in rock slides. The plate thickness is such that it gives, with sodium light, between crossed Nicols, the purple of the first order. Double refraction would change that purple. When the path difference in the plate amounts to nearly half a wave-length of yellow light, white patches are produced by double refraction, and such patches will be seen on the edges and other parts of badly cooled glass; this test is very severe. When the glass is partly unpolished, however, the diffused light might be mistaken for white patches. But if the rough surfaces are rubbed with a little cedar-wood oil, this source of error is avoided, and the faults in the specimen, which is examined against the purple background, are strikingly brought out. The light should be nearly parallel, to avoid variations in colour due to varying lengths of path through the mica.

The method of Dr. Reginald Clay, principal of the Northern Polytechnic, Holloway, of determining the refractive index of a transparent solid is based upon the refractometers of Abbé and Pulfrich, and depends upon the measurement of the critical angle observed when light passes from the specimen into a prism of known index. Instead of the hemispherical ball of Abbé or the cube of Pulfrich, Dr. Clay uses a small isosceles right-angled prism of 45 deg., which he places with its hypotenuse against the polished face of the specimen—one face must be polished—a drop of liquid of high refractive index being spread on the hypotenuse. A ray of a sodium light falls on the specimen and emerges from one of the sides of the prism into a telescope; the telescope is turned until the critical angle is obtained, at which one-half of the field appears dark. The process is then repeated with the parts so turned with the table that the ray emerges through the other side of the prism; from the angle between the two telescope positions the refractive index can be calculated or can be read off on the divisions. The liquid used in this case is quinoline or oil of cassia; the point is that the refractive index of this liquid must be higher than that of the glass tested; the liquid does not affect the result then. When the same method is to be applied for finding the refractive index of a liquid, a case likewise demonstrated by Dr. Clay, two equal prisms, both of the same refractive index—which must be higher than that of the liquid—are joined to form a square so that the two hypotenuses are in contact and the liquid is a film between the two hypotenuses. When the critical angle is reached the light is unable to pass from the first prism into the liquid. The two prisms are pressed against one another and are kept in position simply by the aid of two small cubical wooden blocks. Dr. Clay's instrument for measuring the angle between the axes of a pair of binoculars and their magnifying power is of a similar simplicity. The instrument consists of lamp, collimator with scale, instrument on a lateral slide, and telescope with scale. Without the instrument in position the two scales coincide; when the instrument is put on, the scales should again axially coincide, but overlap, thus indicating the magnification; the slide is now pulled so that the second axis comes in position; everything will appear as before, if the axes be parallel. To determine focal length Dr. Clay places the lens or instrument in a V-groove (of wood) which slides in a similar V and can be turned about its vertical axis between a reflector and an illuminated screen.

Messrs. G. Cussons, of 231, Strand, exhibited the dioptermeter of Professors W. Haldane Gee and A. Adamson, for measuring the curvature of cylindrical and spherical lenses. The "Pointolite" lamp of the Edison-Swan Electric Light Company was noticed by us when first brought out. A spherical bulb contains a small tungsten bead on a stem, from which the arc strikes over to an "ionising" bar, giving a very concentrated, steady light; the lamps are for the range 100 to 250 volts.

Messrs. Adam Hilger, Limited, of 75A, Camden-road, N.W., exhibited a novel arrangement, an adaptation of the Michelson interferometer, for the finishing of prisms and lenses or combinations of the same. Description of this apparatus, which is for the use of the men (not of experts) is not desired by the firm at present; it attracted much attention. Examples of superior flat work and a Pulfrich refractometer made by the firm were also on view.

Messrs. Henry Hughes and Son, of 89, Fenchurch-street, E.C., showed a direct-reading microscope for measuring focal lengths up to 18 in., for checking grinding tools, concave and convex, and for measuring shallow curves with the aid of Newton rings without the use of a bench. Their focometer, due to Mr. T. F. Connolly, deals with single positive lenses (3-in. maximum focal length) and lens combinations (up to 2½ in.); the distance between the lens and focal plane is measured on a simple stand.

The Inspection Department (D.I.O.S.), Woolwich, had a variety of apparatus on view. Their scale for testing angles at about fifty yards distance is made of wood, painted black, and of thin sheets of white celluloid inserted in saw cuts; these celluloid graduations are simply scraped when they get dirty. An iron plate with small square and round holes serves for examining the definition of binoculars, &c.; at 100 yards these holes should appear sharp-edged and free of colour. The sensitiveness of spirit levels is tested on a table which has an up-and-down and also a rolling movement. The azimuth-angle tester is a more complicated apparatus. The instrument under test is clamped to the apparatus and laid on a distant point or a collimator; the azimuth scale on the instrument is set to some angle, and the scale on the apparatus is set to the same angle in the opposite direction. When the worm wheel on the apparatus begins to show wear it should be recalibrated with a standard theodolite. Binoculars are tested in a very compact box, convenient for use at the front, due to Messrs. Troughton and Simms. Strains in binoculars are detected by means of a polariscope, the bright spot in the eyepiece being viewed through a Nicol prism and a lens held in the hand; when a piece of talc is held over the lens the strain becomes more distinct.

Professor H. Jackson, of King's College, explained his weathering test for glass. The prism to be tested is subjected to the action of steam under pressure for three or more hours in an autoclave; when the glass afterwards looks like a piece of ice to which snow crystals are adhering, there is considerable weathering. A similar digester is used at Woolwich.

The novel apparatus of Mr. L. C. Martin, of the Imperial College of Science, can determine the refractive index of irregular unpolished glasses, whilst most

apparatus require at least one polished surface. The specimen is suspended, within a prismatic (triangular) cell with plane-parallel walls, in a liquid mixture (carbon disulphide and alcohol, or solution of mercuric iodide in potassium iodide), the composition of which is adjusted until the refractive indices of specimen and liquid are identical, which is ascertained by focusing, for example, a hydrogen-tube line, the cell being placed on the table of a spectrometer. The liquid in the cell is stirred by a rod turned about its longitudinal axis by a small electric motor. This immersion method is very convenient for testing binocular prisms, for example, before polishing them.

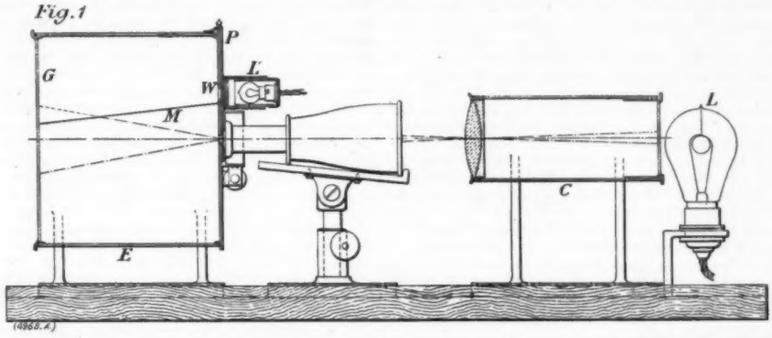
The National Physical Laboratory demonstrated the use of two novel tests. Dials painted with radium-luminous compounds are tested by Mr. J. Walsh by placing the dial between two "artificial" dials, on the left and right, and varying the luminosity of the latter until the intensity is matched. The artificial dial is made by cutting a stencil exactly to correspond to the specimen to be examined, a pair of stencils being wanted for each type. The artificial dials are in front of a screen of paper (two thicknesses), with a green filter (the Wratten minus-red filter being suitable) interposed; behind the screen is a lamp, and the instrument is standardised like a photometer for various current intensities of the lamp. The real and artificial dials looked exactly alike; over 5,000 dials have already been tested. The second apparatus is

The spectroscopic cameras of Messrs. Penrose and Co., of 109, Farringdon-road, are provided with diffraction gratings and designed for testing photographic plates, colour filters, dye solutions, &c.; quartz trains are wanted.

The optical bench of Messrs. Raphael, Limited, of 59, Hatton Garden, E.C., is specially intended for the use of students preparing for the examinations of the Spectacle-Makers' Company or of the British Optical Association. The firm also showed a pocket form (like a watch) of a spectacle lens measure. Demonstrations of silvering on glass were given by Mr. W. Shackleton, of the India Stores Department, Belvedere Road.

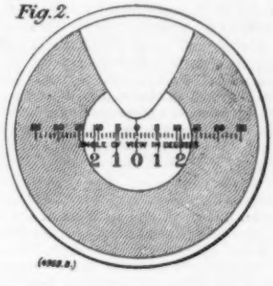
We illustrate, in Figs. 1 and 2, Dr. C. V. Drysdale's field-glass tester for determining magnifying and illuminating power and field of view, one of the exhibits of Messrs. Tinsley and Co., of Eldon Park Works, South Norwood. The essential parts (all mounted on a slide) are the artificial eye camera E (Fig. 1), the table for the binocular in front of it, the collimator C, the lamp L and the small auxiliary lamp L^1, attached to E. Divisions of 1 deg. are marked both on the screen of C and on the "retina" wall G of E, on which the light from the collimator is focused. These two scales coincide when there is no instrument lying on the table; when the instrument is put in position, the latter scale will overlap a certain number of divisions of the former (Fig. 2), and

Fig. 1



(4968.A.)

Fig. 2.



(4968.B.)

square, but if the definition be faulty or the prism have a pyramidal error, the square will be distorted.

Messrs. W. Watson and Sons, of 313, Holborn, use glass discs, equatorial segments of polished spheres, as primary standards of curvature.. In their new prism-testing machine for the workshop the horizontal face of the prism is placed on a five-point bearing (steel balls) and the vertical face bears against the lower end of a magnifying lever, the upper end of which moves under spring pressure in the field of a microscope reading to 20 seconds of arc. The machine is standardised with the aid of a block of glass having four perfectly polished faces approximately at right angles; the mean of the four angles measured must, of course, be exactly a right angle In the micrometer for measuring the separation of the lenses in a microscope combination, the objective is inserted in the hollow of a screw; a Brown and Sharpe micrometer head fitted with a ball point is brought down in succession on the several upper faces of the component lenses. In the same way a Brown and Sharpe micrometer measures the thickness of large lenses. The ring spherometer of the firm also makes use of this remarkably accurate micrometer head, and differs from the usual type of spherometer also by taking its bearing (on the surface to be measured) on the sharp edge of a complete steel ring, so that the diameter of the circle can be exactly measured. Another apparatus for determining curvature of polished surfaces by the microscope is based upon the principle that a reflecting surface has two positions in which object and image coincide, viz., when the object is in contact with the surface, and again when the object is at the centre of curvature. The object is formed by a lamp, the image of which is reflected down the microscope by a mirror at 45 deg., and the distance is measured through which the instrument has to be focused to pass from one of the positions to the other. This can be done within 0.1 mm., even with small, irregular fragments of polished surfaces. The novel naked-eye test of Mr. Conrady (of the firm) for right-angled prisms makes use of the "optical square" reflection, which, though faint generally, has to be eliminated. In a right-angled prism the angle between the incident and the twice-reflected ray is constant only for certain angles, especially for grazing incidences. If the prism is so held by the observer that the light of a tungsten lamp is seen at nearly grazing incidence, and the lens then turned a little to right or left, the width of the lamp, *i.e.*, the distance between the metal filaments, will appear to change, to expand or contract, when the angles differ very slightly from their correct values.

Messrs. Wood Brothers, of Barnsley, exhibited a great many samples of British sands and of specimens of glasses made from the sands, in order to demonstrate that certain sands give glasses free from any colour tint.

Mr. J. Guild's arrangement, already briefly mentioned in our columns, for testing the refractive properties of optical glasses by means of a Pulfrich refractometer (made by Messrs. Zeiss). The hydrogen spectrum is used for the test, and is produced in a glass cell of H-shape, the glow in the horizontal bar being watched end on. Such a cell, charged with rarefied hydrogen, will answer for a short time, but will then deteriorate, owing to gas discharge from the electrodes and walls. To make the cell last 70 times longer it is joined to a large bulb (1½ litres), also containing rarefied hydrogen. When a large amount of testing has to be done, another method is employed. The H-cell is joined to an electrolytic hydrogen generator (a kind of Kipp bottle arrangement with nickel gauze electrodes), and a branch connection is made with an oil pump. When wanted, the cell is flushed with hydrogen (to wash out air that may have leaked in) and then evacuated by a few strokes of the pump. To determine the index within one or two units of the fifth decimal, for four wave-lengths, takes from ten to fifteen minutes.

Among the many exhibits of the Optical Department of the Ministry of Munitions we notice a novel apparatus for testing parallax in telescopic sights for rifles. The method makes use of an artificial eye; the eye of the observer has not, as in other apparatus, to be moved to and fro, which is unsatisfactory, this movement being imparted by a slide to the pupil of the artificial eye. The observer sees in the telescope a vertical pointer and two cross lines, and the pointer should keep its position with regard to the cross lines when the pupil is shifted. In the apparatus for testing the parallelism of prismatic binoculars two collimators and the telescope are mounted parallel to one another; the telescope can be shifted laterally, and the binocular is adjusted between the telescope and collimators until the cross wires of one of the collimators are projected on the cross wires of the telescope; the telescope is then shifted over to the second component of the binocular and the displacement measured. The method is thus the same as that of Dr. Clay. Angles of prisms are tested with the aid of auto-collimating telescopes in which part of the eyepiece scale is illuminated. The polariscope for testing optical glass is so arranged (as in Bennett's doubler) that the light passes through the prisms in the same direction as in the instrument itself; the polarised beam is reflected down vertically by a black plate. There were also several focometers, one after the Zeiss patent, No. 12,100 of 1914. A simple lens-centring stand, due to Messrs. Culver, should also be mentioned.

thus the magnifying power (5½ diameters in the diagram) is directly read off. In the camera E will be noticed the partition M, which cuts off the upper part of this camera; this part is illuminated by the small lamp L^1, which is in series to L, through the window W; L^1 slides in its tube, and is shifted until the parabolic light spot (Fig. 2) from L^1 is equally as bright as the circular spot from L. When the binocular is interposed the main field will be darkened; the window W is then closed by a sliding shutter until equality of illumination is restored; a pointer P attached to W then indicates the percentage of the illumination of the field compared with that of the object as seen by the fully open pupil (5 mm.), being the aperture of the lens of E.

The binocular parallelism tester of Dr. Drysdale is a vertical stand on which two collimators are vertically fixed side by side; into the lower end of each collimator fits a small Osram lamp. The two collimator beams are brought to focus by a lens of 1 m. focal length; a bright circle is then seen on the screen above. When the binocular is placed immediately above the collimator, the bright circle is enlarged if the axes be parallel; if not parallel, the bright circle is divided into four sectors, which are separated by bright or dark bars, or which overlap. Messrs. Tinsley also showed a small definition tester, a supplementary eyepiece to be slipped over the eyepiece of a telescope, microscope, &c.; it contains an accurately-worked plane-parallel glass at 45 deg., reflecting the light of a distant source down the instrument.

Messrs. Troughton and Simms exhibited an 18-in. level (double-wire micrometer), a 5-in. theodolite reading to 10 seconds directly, and a bench tester for binoculars.

The micrometers for measuring the angles of prisms before polishing, exhibited by the Uni-Bifocal Company, 40, Gloucester-street, Rosebery-avenue, W.C., are solid angles of 90 or 45 deg., made up of steel plates, in which the prism rests on four rounded studs or balls. The measurements are made with the aid of micrometer screws passing through the steel plates or through an arc in front of the acute angle; by shifting the position of the prism in the angle, parallel to the edge, measurements can be made at different spots of the prism. In their telescope and artificial star for testing the definition of a prism, the prism is so placed on a stand that the light of the distant point (star) falls on one side and appears as a point on the screen when the telescope is properly focused; when the telescope is pulled out of focus the point turns into a

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THE NEW HAZELL ANNUAL AND ALMANACK.—This publication, edited by Mr. T. A. Ingram, M.A., LL.D., now appears under the joint proprietorship of the Oxford University Press and Messrs. Hodder and Stoughton, from either of whom it can be obtained at the price of 3*s.* 6*d.* net. It contains a vast amount of information on the British Empire and every country of the world, and upon practically every subject in current life. The book proves most useful for reference purposes.

INSTITUTION OF NAVAL ARCHITECTS.—The annual meetings of the Institution will take place on Wednesday, March 28, and the following day, in the Hall of the Royal Society of Arts, John-street, Adelphi, W.C. The Right Hon. the Earl of Durham, K.G., G.C.V.O., P.C., president, will occupy the chair. The council will be willing to present a gold medal to any person, not being a member or associate member of council, who shall at the forthcoming meetings read a paper which, in the judgment of the council, shall be deemed to be of exceptional merit. The council will also be willing to present a premium of books or instruments to the reader of any paper, not being a member or associate member of council, which paper shall, in the judgment of the council, merit this distinction.

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics gives, in the *Board of Trade Labour Gazette*, an annual review of certain statistics dealing with the industrial situation in 1916, and states that the demand for labour in 1916 was unprecedented, partly owing to the depletion of industry through enlistments, and partly to the great requirements of the Allied forces. At the beginning of the year there was already a marked shortage of labour, and this was accentuated by continuous enlistments. On the other hand, the "dilution" of skilled labour by semi-skilled or unskilled labour was carried out to a much greater degree than had hitherto been attempted, and there was a notable extension in the employment of women and girls. The shortage of labour had also been met to some extent by the working of overtime and by the voluntary movement of workpeople from one industry to another. In spite of all expedients, however, the demand for labour far exceeded the supply, and there was now urgent need for a further development of concentration of the available supplies of labour on work of national importance.

The upward movement of wages which was such a notable feature of 1915 was no less marked in 1916. The movement was attributable to the great demand for labour and to the continuous rise in prices, and embraced not only those workpeople whose wages had not been advanced since the beginning of the war, but included most of the great bodies of organised labour who had previously benefited by the increases granted in 1915. The industries in which the largest number of workpeople obtained increases were coal-mining, textile and metal trades. Substantial advances in wages were obtained in the transport trades, and there was a stronger upward movement than in the previous year in the building trades. So far as reported it appears that since the beginning of the war and up to the end of December, 1916, nearly 6,000,000 workpeople had received some advance. The amount varied, but, on an average, the weekly increase to these workpeople was about 6*s.* per head, and in some of the industries directly concerned with the supply of war requirements it ranged from 10*s.* to 12*s.* per week. In this connection it should be noted that these figures relate to increases in rates of wages, and they take no account of increased earnings due to more regular employment and overtime.

On the other hand, there had been a considerable increase in prices. Retail prices of food at the beginning of 1916 were about 45 per cent. above those of July, 1914. On January 1, 1917, the corresponding increase was 87 per cent., the advance during 1916 amounting to 42 per cent. on pre-war prices. Of this 42 per cent., only 15 per cent. accrued up to August 1, and the greatest increase in any one month was in October, viz., 10 per cent.

The average increase since July, 1914, in the cost of all the items ordinarily entering into working-class family expenditure was estimated at about 60 per cent. at January 1, 1917, as compared with 30 per cent. a year earlier, eliminating the effect of increased duties, and taking the same quantities and descriptions of the various items at each date. These figures indicate the relative levels of prices at the respective dates, but take no account of alterations in dietary which have in many cases been effected since the beginning of the war.

There was a further falling-off in the number of labour disputes and in the number of workpeople involved therein, and in their aggregate duration in working days. At the end of the year 1916 only 10 small disputes, affecting in all 739 workpeople, were in progress.

Dealing with the British labour market in December, 1916, the Director of the Department of Labour Statistics says that in that month there was, on the whole, no falling-off from the high level of employment which has been maintained for many months in most of the principal trades, and especially in those supplying the requirements of the forces.

The changes in rates of wages reported as taking effect in December, 1916, affected about 362,000 workpeople, and resulted in a total increase of about 55,400*l.* per week. No decreases in wages were reported. The principal changes affected coal miners in South Wales and colliery surface workers in Scotland; pottery and tile workers in Staffordshire; boot and shoe operatives at Leicester; and iron puddlers and millmen in the Midlands.

The number of disputes beginning in December was 14, and the total number of workpeople involved in all disputes in progress was 36,627, as compared with 38,647 in the previous month and 8,817 in December, 1915. The estimated total aggregate duration of all disputes during the month was 187,300, as compared with 155,000 in November, 1916, and 74,800 in December, 1915.

The average weekly number of vacancies notified to all Employment Exchanges for the four weeks ended December 8 was 39,762, as compared with 41,113 in the previous four weeks, and with 36,820 in the four weeks ended December 10, 1915. The average weekly number of vacancies filled for the same periods was 30,405, 31,778 and 24,829 respectively.

The Secretary of State for War has reconstituted the committee dealing with proposals for the employment of prisoner of war labour, and each application for the employment of prisoners of war, combatant or civilian, will be laid before the committee, who will consider its relative national importance and will decide whether it should be adopted. All applications from Government Departments not represented on the committee, and from private employers, should be forwarded to the Secretary of the Committee, War Office, Whitehall, S.W.

The Minister of Munitions has ordered that no person shall, as from the 11th inst., until further notice, purchase or take delivery of any gas-works retort carbon except under and in accordance with the terms of a permit issued under the authority of the Minister of Munitions. And, further, that no person shall, as from the same date, until further notice, sell, supply or deliver any gas-works retort carbon to any person other than the holder of such a permit as aforesaid. All applications for a permit should be addressed to the Director of Materials (Reference A.M. 2, F.W.H.), Armament-buildings, Whitehall-place, Whitehall, S.W.

The Minister of Munitions gives notice that he prohibits, until further notice, any person from carrying out, except under and in accordance with the terms of a permit issued under his authority, any work consisting in the manufacture or erection of any machine, implement, vehicle or other article or any part thereof, designed or adapted or commonly used for agricultural or dairy purposes, provided that the Order shall not prevent the completion of any work remaining to be done under a contract in writing entered into before the date of the Order (the 10th inst.), upon any article of the nature aforesaid intended for use in this country, or the carrying out of any necessary repairs. All applications with regard to the Order should be addressed to the Director, Agricultural Machinery Branch, Armament-buildings Whitehall-place, S.W.

The Lords Commissioners of the Admiralty have decided to extend the department under the Third Sea Lord for organising labour in the shipyards and marine engineering shops of the country. Mr. Lynden Macassey, K.C., has been appointed head of the reorganised department under the title of "Director of Shipyard Labour." It will be the duty of the department to secure, organise and use to the best advantage, on a uniform national policy, all available labour required for the construction of war vessels and merchant ships. For this purpose the Minister of Munitions has agreed to transfer to the Admiralty all necessary powers which are vested in him over shipyards and marine engineering establishments. The department will work, so far as the obtaining of labour is concerned, in conjunction with the Director of National Service, and in regard to the transfer of labour from yard to yard through the machinery of the Ministry of Labour. It will also work in close co-operation with the Ministry of Labour in regard to the determination of labour disputes.

The particular attention of employers is directed by the Secretary of the War Office to the new Regulation 41A, which entirely replaces the previous regulation as amended, and also imposes new obligations on employers of male persons between the ages of 18 and 42. Such employers must now prepare three statements, namely:—

Statement No. I (corresponding to the list previously required): Giving particulars of male employees between 18 and 42 who have been employed for a week or more. *Statement No. II:* Of the total numbers of female employees of any age who have been employed for a week or more, and of male employees so employed who are not within the ages of 18 to 42. (This is a new requirement.) *Statement No. III:* Of male employees between the ages of 18 and 42 who have been employed during the preceding month for less than a week (whether still employed or not). (This corresponds to the former record of casual employees.)

The first two statements must be kept posted up conspicuously, as previously required, but the third need not be posted. Employers must deliver forthwith to the appropriate Recruiting Officer a copy of each statement which they have to prepare, and in the first week of every calendar month must also deliver to him a written report of alterations and additions down to the end of the preceding month. The cases where employers are exempted wholly or in part from compliance with the regulation are in substance the same as under the previous regulation. It will be noted that 42 is substituted for 41 as the higher age limit of certain affected employees, and that the regulation affects only persons who employ one or more male persons between the ages of 18 and 42.

An interesting address on "Education and Business" was delivered by Mr. W. L. Hichens, chairman of Messrs. Cammell, Laird and Co., at the twenty-fifth annual meeting of the Incorporated Association of Headmasters, held at the Guildhall, on Tuesday, the 9th inst. On the particular question of engineering Mr. Hichens dealt with the better-educated apprentices, those who had had the advantage of a secondary education, adding that it would be a great mistake to think that the higher posts were open only to those better-educated youths, for industry was far more democratic than was generally supposed, and merit was rightly recognised wherever it was found. With reference to the apprentices in question, they should enter the works between the ages of 16 and 17, and, if possible, after serving an apprenticeship in the shop and drawing office, they should enter a university and take an engineering course.

He often wondered why it was that the number of public school boys who chose engineering as a profession was so small, since we now lived in a mechanical age, and our material progress was more closely bound up with engineering than with any other profession. If, for example, we were to harness the great untrained forces of Nature and cause them to minister to our needs, we looked to the engineer; if we wished to increase the wealth of the world, and to raise the general standard of well-being, we had to look to improved mechanical devices, for it was only by labour-saving machinery that we could gain the freedom from unremitting toil at which modern civilisation aimed. And yet one found that boys preferred the counting-house or the Army or the Civil Service to engineering. Why was this? Partly, he thought, because few scholarships were offered to boys to carry them through their period of apprenticeship. But the main reason was perhaps that the engineering career did not offer the same certainty as the others he had mentioned. These others were miserably paid, as a rule, but they offered a safe though modest competence, and during recent years boys had been taught, and very wrongly so, to go for the safe thing.

But reverting to the recruiting of apprentices, he preferred that they should enter the works at the ages of 16 and 17, as above stated. Works had recently also reserved a limited number of vacancies for university men. The research department should, in the main, be recruited from university men. But whereas the latter should have received a scientific training at the university, the works required no specialised education in the case of university men joining the commercial side. They preferred either comparatively young boys of 16 or 17, or else young men who had completed their university career. There was no great scope for the boy of 18 or 19 who had spent two years longer at school. In practice they found that the boy of 18 or 19 had not acquired any special advantages by his two extra years at school which enabled him to outstrip the boy who had started his business career earlier. The cause for this might be—not that the education of the older boys ought to be more highly specialised or "vocational"—but, on the contrary, that there was a tendency at those ages to desert education for practical training, and neither was achieved. The fact was that specialised education at school was of no practical value to works owners. There was ample time (after a boy had started on a business career) in which he could acquire all the technical knowledge that his brain was capable of assimilating, and it was the duty of every firm to see that its apprentices received a proper training.

It was also the duty of every manufacturing town to see that efficient technical schools and continuation classes were maintained.

In the sheet for January, entitled *Empire Trade Notes*, issued by the British Empire Producers' Association, it is stated that one of the trades favourably affected by the war is that concerned with the manufacture of glass bottles; and its revival has been assisted by an extraordinary departure by the Glasgow district trade union interested in this department of industry. The question of restricted output has in this case been promptly and decisively dealt with by the men themselves, with whose full authority the secretary of the society, Mr. Peter McLuskey, recently visited America to inspect modern methods of production, and on his return described his experiences to the British Empire Producers' Organisation. With the support also of the manufacturers Mr. McLuskey arranged for the importation not only of high-production machinery, but also of a number of American workmen for instruction in its use. The result is that the Glasgow district bottle makers, whose rate of wages was rather

higher than that paid in America, but whose earnings were considerably less, owing to inefficient organisation, will be in a position to gain a substantial increase of income, and will be much more secure in their employment. Previous to the war, say the *Notes* in question, the industry was dominated by the German manufacturers, who only permitted a fixed limited output of British bottles.

The following statements are taken from the report of an interview which Mr. W. A. Appleton, secretary of the General Federation of Trade Unions, recently had with Mr. Joseph W. Griggs, special staff correspondent of the *New York World*. Mr. Appleton said:—"The British workman—and workmen constitute 85 per cent. of the British fighting forces—entered the war to defend Belgium. The complete restoration of Belgium is, above all else, the principal thing for which he is still fighting . . . I would beg of all the workers of America that they permit neither political prejudice nor personal convenience, nor personal gain, to stand in the way of their efforts to bind up the wounds of Belgium, to restore her to her place among the nations, and to secure that her children shall know that the sacrifices she made were not in vain . . . No exaggeration is possible when speaking of the brutality with which Germany has treated Belgium . . . There are men in the British labour movement who have been in touch with the German labour movement, but I do not see how it would be possible for them to continue to resume their association with Germans. I am satisfied from my own personal knowledge of Great Britain, and from my association with British workpeople, that those who condone the frightfulness of Germany are very few in number, and that they represent only the smallest minority of the working-class thought of this country. I have studied the innate sense of justice and right which characterises even the roughest of the workers of Great Britain, and I am satisfied that neither now nor in the future will they tolerate association with the German working-class movement unless the German working-class movement immediately and forcibly repudiates the dastardly acts of the German Government . . ."

BRITISH AND ALLIED SHIPPING.—A Board of Trade Regulation under the Defence of the Realm Acts was published on the 12th inst. regulating the chartering of vessels in the trade to or from British ports. Similar regulations are being made in France and Italy, and the new measure is designed to secure closer co-ordination between the Allies in the employment of tonnage. In future, permission will have to be obtained from a national authority in each country before any foreign tonnage is chartered. In the case of the United Kingdom any person who wishes to obtain permission to charter a foreign ship should send full particulars to the Marine Department, Board of Trade, London, S.W., marking the envelope "Charters."

THE SHORTAGE OF RUBBER IN GERMANY.—According to a report issued by the United States Vice-Consul at Frankfort-on-Main, the first substitute for a cycle tyre to appear was a tyre made of steel wire, about $\frac{3}{16}$ in. thick, made up into a very close coil, the two ends being welded together so as to give it the proper shape. The wholesale price of this product is now 12 marks, and it is retailed for 18 marks. The price is high, and the tyre has cut into the pavements, and rattles considerably. Wooden tyres have been used with some success. At least three different types of which wood is the main part are sold. One is made by the Continental Caoutchouc and Gutta-Percha Company, of Hanover. It is of 47 parts. There are 12 wooden tyre sections of 3 different kinds, 12 tin plates, 12 screws, 10 connecting pins, and 1 thumbscrew. The tin plates are used to secure the sections to the rim, which must be of metal, the screws to attach the tin plates to the ends of the sections, the connecting pins to hold the sections together, and the thumbscrew is put through the valve hole in the rim, and thus tends to attach the tyre more firmly to the rim. The company is selling this tyre for 6 marks. In reality the expense is more, for shock absorbers in the form of steel springs must be attached. A third wooden tyre is made of one piece of wood, the outer surface of which is covered with a small strip of leather. Between the under surface of the tyre and the rim several steel springs are placed, with a view to securing elasticity. In addition to this, large steel springs are attached to the front and back forks. The cost of this outfit, including the two tyres and the large springs is 36 marks. Several leather-covered and canvas-covered tyres are also on the market. These are solid, the outer casings being of leather or prepared canvas, and the inner part consisting of wood and other substances. To make the tyre more durable small pieces of steel are often affixed to the outer or wearing surface. One fairly good leather-covered tyre retails at 48 marks a set, another at 70 marks. The tyre that is said to have the strongest claim to being a real substitute for the rubber article appears on the market under the trade name of "Lobo." It is made in Chemnitz, Saxony, by the Kunstgummi, G.m.b.H. It is of two parts, the inner part being solid and covered with cloth made into the shape of a tyre. The tube is filled with a preparation resembling rubber. The outer tube is of prepared canvas, and is said to have very good wearing qualities. The price for a set is 52 marks.

PROTECTION-EDGE LAMINATED BELTING.

BELTS on a planing machine are shifted from pulley to pulley every minute, sometimes every few seconds. There is therefore great wear on the edges, due to the friction of the belt forks, and the edges may be worn out while the centre of the belt is still in capital condition. The result is that extensive repairs are required, involving delay and expense. To prevent this occurrence Messrs. John Tullis and Son, Limited, of St. Ann's Leather Works, Glasgow, have just introduced a protection-edge laminated belt, in which a special wearing piece is introduced on each edge. The belt itself, in the specimen sent us, is made of laminæ, $\frac{1}{4}$ in. by $\frac{3}{16}$ in., set on edge and sewn right through from edge to edge of the belt, the stitches lying on the neutral axis. The outer lamina on each side is hollowed on its outer face, as shown in the accompanying section, and

the protection strip is laid in this hollow. This strip is originally 1 in. wide by $\frac{3}{16}$ in. thick, and it is laid against the edge of the belt like the flange against the web of an H-joist. The stitches pass first through the protection strip, then through all the laminæ, and finally through the second protection strip, binding them all firmly together. When the sewing is complete the protection strip is bent into U-form, as shown, and the two limbs of the U are sewn tightly together, a layer of cement being interposed between them. The protection strip thus becomes flush with both surfaces of the belt, and its outer edge is finally rounded off.

The makers inform us that the belt answers immediately to the touch of the belt-fork and changes pulleys instantly, effecting a marked saving of time. In a recent trial a saving of nine hours per week was registered. As there is no cross-joint, since the joints in the various laminæ occur at different places, there is no jolt or jar as the belt passes over the pulley.

THE ANOMALY IN SUPERHEAT CORRECTIONS: ERRATUM.—On page 36 of our last issue, column 2, line 5, for "superheated steam" read "supersaturated steam."

ELECTRICITY AND ITS APPLICATIONS.—Lectures to juveniles, essentially experimental, have for a long series of years been delivered during the Christmas recess at the Royal Society of Arts, as well as at the Royal Institution. At the Society of Arts Mr. A. A. Campbell Swinton, F.R.S., was this year's lecturer, and the subject of his two lectures, given on the Wednesdays, January 3 and 10, was "Electricity and its Applications."

"REVUE GENERALE DE L'ELECTRICITE."—We have received the first number, dated the 6th inst., of this journal, which combines the former journals *La Lumière Electrique* and *La Revue Electrique*. It is divided into a scientific and technical section, an industrial section, one dealing with resources and finances, one on legislation, and accounts of the meetings of the French electrical associations. We wish the journal every success.

JAPANESE-AMERICAN COMPETITION IN SIBERIA.—In spite of its immense natural resources Siberia has, in reality, received hitherto but scant attention. The vast country was a convenient market for certain Russian industries, and some banks started branches in the larger towns, but there appeared, nevertheless, to exist in this a certain lack of purpose. The war, however, has wrought material changes in this respect, and in a direction which, it is stated, causes some apprehension in Russia. Foreign manufacturers and merchants have made their appearance on Siberian soil in no small numbers. At the same time, home industries are springing up for handling the raw materials in the country, and existing concerns are being developed into more or less important companies. Further, increases are recorded in bank deposits. To work up this vast country large capital sums are needed, and both Americans and Japanese seem anxious to supply them. Thus representatives of large American banks have arrived in Eastern Siberia, in order to study the ore and coal deposits; another scheme is the formation of a large general agency for American agricultural machinery in Siberia, and the chemical products of the Russo-American Company have already made their way into small Siberian towns. Even American petroleum, which for years was forced out of the Siberian markets by Russian petroleum, is now again being imported in large quantities. A similar activity is displayed by Japan. A Japanese General has recently started a company with a capital of 17,000,000 yen, which is to trade with Siberia. Another Japanese group of financiers is negotiating the acquisition of large graphite deposits. Various other undertakings are receiving offers and inquiries from Japanese banks and capitalists, anxious to take an active part in the opening out of Eastern Siberia. It is easy to understand that the foreign invasion causes some apprehension, and "Siberia for the Siberians" is a heading frequently met with in the press of the country.

ELECTRON, QUANTA AND RELATIVITY THEORIES.

TO THE EDITOR OF ENGINEERING.

SIR,—"Sesamy" objects to the phrase "matter and motion," which, he says, is mere nonsense to anyone who realises the meaning of matter in motion. I suppose, however, he will admit that if anyone ever did realise that meaning it was Maxwell, who, in a small work dated 1888, used both the sub-titles "Matter and Motion" and "Matter and Energy." For careless use of expressions we need only refer to "Sesamy's" letter dated Christmas Day, where he says "the temperature of any substance is not raised by heat entering into it," &c., &c. I have tried to answer his conundrum: "How can an amount of energy or momentum *enter* at W or anywhere else?" A ray of light is also a ray of heat, or of energy, or of momentum, and it can enter a transparent substance at any point. I have analysed its vibrations both at the source and on the line of transmission. I can do no more. When "Sesamy" spoke of his "serious study of what Relativists try to say" I anticipated a real contribution to the discussion, but so far we have gained nothing but invective. Invective we must employ to detach established theory from falsehood, but it is necessary to build up as well as to pull down.

Professor Jeans admits that "For the physical interpretation of the quantum theory the precise question which is of importance is whether the ether has so much of substantiality that it must be treated as part of the dynamical system in connection with which it occurs." Maxwell, however, *insists* on a substantial ether throughout his treatise, and reaches a climax in his ultimate sentence, as follows: "Hence all these theories lead to the conception of a medium in which the propagation takes place, and if we admit this medium as an hypothesis, I think it ought to occupy a prominent place in our investigations, and that we ought to endeavour to construct a mental representation of all the details of its action, and this has been my constant aim in this treatise." In your issue of January 5 (page 18) I determined the specific density of the ether at 0.575 from the velocity of light. Is there no correspondent who will criticise this determination? In the penultimate paragraph of that communication I wish to correct—"a magnetic component H *parallel to the axis*"—which should read, "in the plane of the axis."

H. L. Stewart, in his "Questions of the Day" (page 18), says: "The blinding power of a theory is almost incredible: persons of ordinary honesty in the affairs of life, once they have espoused a dogma will, all unconsciously, invent, suppress or distort facts, and suborn evidence to a degree that must be seen to be believed." That, Sir, I submit, is the one and only reason why existing theories will not reconcile. Both the exponents of the quantum theory and the electron theory, the latter including the Relativists, have imbibed the poison of which Maxwell again and again warned us. New methods demand new men, and I look with confidence to the younger generation of scientists, especially those who are in any degree self-educated, the only education which puts a man on his mettle to test established theories for himself before he imbibes their physical hypotheses.

FRED G. EDWARDS.

33, St. Ronan's-road, Sheffield, January 13, 1917.

THE LUBRICATION OF GEAR TEETH.

TO THE EDITOR OF ENGINEERING.

SIR,—The article on "The Lubrication of Gear Teeth" which appeared at page 110 of the issue of ENGINEERING of August 4 last is undoubtedly a most important contribution to this subject. Though it is mainly founded on theoretical considerations, it puts forth statements that open our eyes on many points and will raise more than one question. But, of course, engineers are bound to believe in results of quite proved experience rather than in data theoretically ascertained, and even after the reading of a very clever article they will still incline towards practical data.

It is perhaps too early to arrive at any definite formula as to the load which may be safely transmitted by double-helical modern high-speed gearing, only a few years having elapsed since the appearance of the first well-designed large reduction gear. England certainly possesses the engineers who will in due course of time illuminate the questions which are being raised by the new investigation on "The Lubrication of Gear Teeth."

Some reader of this most valuable article will perhaps feel interested in results which were arrived at some ten years ago by closely examining and studying the working surfaces of accurately cut spur gears, which had been running quite satisfactorily. It was first suggested that the capability a pair of teeth has to transmit load by their *mutual contact* varies along the path of contact. Actual observations showed the points at which the security against abrasion was a minimum and at which some slight wear could be detected with time, however diligently lubricated were the teeth. The load which the wheels were safely transmitting was well known, and we have reckoned that the intensity of the specific pressure on the bearing surfaces of all the wheels considered reached at the weak points some 13 kg. per square millimetre (18,800 lb. per square inch). This maximum value of the pressure was very nearly the same for all pinions and all spur wheels actually examined, however small or great were the number of teeth, and for values of the circular pitches ranging from $\frac{1}{2}$ to $2\frac{1}{2}$ in. It at once appeared that this value would make a good experimental basis for determining the load which could be transmitted by cast-iron cut wheels as far as security against abrasion is concerned. Therefore, assuming $p_{\text{max.}} = 13$ kg. per

square millimetre, and applying to the curved surfaces of the teeth (bearing at the weak point) the same laws of elasticity which had yielded the value of p max., we determined the load which would have been safely transmitted by any pinion gearing with any wheel.

The results of this investigation have been combined into a formula which was first published in 1906, in the Italian paper *Il Politecnico*, Milan, then republished in 1909 in a small book on transmissive machinery ("Trasmissioni Moderne—Castellanza," 1909, pages 386 to 389), with a slight difference as to the factor of velocity, which was kept of smaller importance than it was made in 1906. The relative values of the ψ function remained the same. Let

P kg. be the load to be safely transmitted by cast-iron cut teeth wheels,
ψ the value of a function—as given by Tables I and II depending on
Z_1 number of teeth in pinion,
Z_2 number of teeth in wheel,
$p_{max.}$ kg. per square millimetre maximum specific pressure,
M mm. the metric module = circumferential pitch in mm. $\div \pi$,
L mm. length of teeth,
V m. per second speed at pitch circles,

Then

$$P = \psi \, M \, L \, \frac{1}{V + 10} \text{ kg.} \quad . \quad . \quad (1)$$

To translate this into British units and to avoid confusion, let

W be the load in lb.,
p the circumferential pitch, inches,
b the breadth of the toothing, inches,
v the speed at pitch circle, in feet per second,
ψ as above,

Then, applying all conversion factors to the last fraction, we may write :—

$$W = \psi \, p \, b \, \frac{1480}{v + 32.8} \text{ lb.} \quad . \quad . \quad (2)$$

The (1) has been experimentally proved true between M = 5 and M = 32 (about ¼ to 4 in. circular pitches) and, to come to a first question, we may state that,

TABLE I.—*Values of ψ for Involute Wheels. Angle of Obliquity 15 deg.*

Number of Teeth in Pinion Z_1.	Transmission Ratio = $Z_1 : Z_2$.							
	1:1	1:2	1:3	1:4	1:5	1:6	1:8	1:10
	Values of ψ							
12	2.80	3.40	3.80	4.20	4.36	4.54	4.80	5.00
14	3.20	3.80	4.20	4.60	4.88	5.08	5.40	5.60
16	3.50	4.20	4.64	5.06	5.36	5.58	5.84	6.10
18	3.80	4.40	5.00	5.40	5.76	5.96	6.24	6.44
20	4.20	4.90	5.40	5.90	6.20	6.40	6.68	6.90
24	5.00	5.76	6.30	6.80	7.04	7.30	7.60	7.80
28	5.70	6.40	7.04	7.60	7.88	8.14	8.50	8.64
32	6.40	7.28	7.92	8.40	8.80	9.04	9.40	—
36	7.20	8.10	8.76	9.24	9.60	9.88	—	—
40	7.90	8.84	9.56	10.08	10.44	—	—	—
48	9.60	10.60	11.40	11.90	12.30	—	—	—
60	11.60	12.86	13.76	14.40	—	—	—	—

TABLE II.—*Values of ψ for Cycloidal Wheels. Rolling Circle to have 12 Teeth.*

Number of Teeth in Pinion Z_1.	Transmission Ratio = $Z_1 : Z_2$.							
	1:1	1:2	1:3	1:4	1:5	1:6	1:8	1:10
	Values of ψ							
12	2.00	2.16	2.24	2.36	2.40	2.48	2.60	2.70
14	3.00	3.54	3.88	4.20	4.40	4.60	4.90	5.20
16	3.94	4.40	4.80	5.16	5.40	5.60	6.00	6.40
18	4.54	5.12	5.60	6.00	6.22	6.46	6.84	7.20
20	5.12	5.80	6.36	6.80	7.10	7.40	7.74	8.00
24	6.00	6.84	7.50	8.00	8.36	8.60	9.00	9.20
28	6.80	7.70	8.40	8.88	9.28	9.60	10.00	10.20
32	7.40	8.44	9.20	9.76	10.20	10.46	12.80	—
36	8.00	9.10	9.80	10.40	10.80	11.00	—	—
40	8.52	9.68	10.40	11.00	11.40	—	—	—
48	9.80	10.70	11.60	12.00	12.40	—	—	—
60	10.40	11.60	12.40	13.00	—	—	—	—

TABLE III.

Transmission Ratios, $Z_2 : Z_1$.	Number of Teeth in		Relative Merit	Loads Ratio.
	Pinion Z_1.	Wheel Z_2.	Values ψ.	
10 : 1	14	140	5.60	1.54
"	28	280	8.64	
8 : 1	16	128	5.84	1.61
	32	256	9.40	
6 : 1	18	108	5.96	1.66
	36	216	9.88	
4 : 1	24	96	6.80	1.75
	48	192	11.90	
2 : 1	30	60	6.84	1.88
	60	120	12.64	
1 : 1	30	30	6.05	1.92
	60	60	11.60	

doubling the circular pitch, the capacity of the pinion to transmit load without undergoing undue wear will be doubled (other things being equal); but if we were to double the diameter of the pinion by doubling the number of teeth, the load will not be twice as much, as we may read from the last column of Table III, which is so composed as to cover well the practical field.

Two years ago we were re-studying the question with the ambitious aim of giving it a general analytical treatment, and it appeared that the flattening and the bending of the teeth could have been considered differently from what we did twelve years ago, but the ψ values would have been affected all nearly the same way and the relative merits of the wheels remained practically unchanged, according to the results of experimental observations.

As to the convenience of a factor to take into account the influence of the velocity, we may observe that high-speed pinions which had made a half milliard revolutions under load were found in better condition than lower-speed ones that had completed the same number of working turns; but the former would not last a number of years if loaded quite as much as low-speed ones.

Since formula (1) was established it has been exclusively applied to the calculation of the transmissive machinery and reduction gears of which our firm had made a speciality, and of which we are still supplying some 80 per cent. of the total amount made in Italy. We have been especially watching the wheels, and the reduction gears to which the (1) gives loads widely different from any other formula (the discrepancy being ± 100 per cent. owing to the variability of the function ψ), and even these extreme wheels behaved just as well as all others.

Five years ago we started manufacturing double-helical gears. There not being available any good practical data for calculating the proportions of such wheels, it was decided—on account of the very much improved form of the bearing surfaces of the teeth—to load them 50 per cent. more than the corresponding plain ones. We practically make :—

Gears.	Loads.
Cast-iron cut spur gears ...	P—as from (1).
Steel cut spur gears	3 P.
Double helical cast-iron cut wheels	1.5 P.
Double helical steel wheels...	4.5 P.

Hence, considering double helical teeth, we write—British units :—

$$W = \psi \, . \, p_n \, . \, b \, \frac{3}{v + 30} \text{ tons} \quad . \quad . \quad (3)$$

Assuming a mean value $\psi = 6$, with a normal pitch $p_n = 1$ in., for $v = 60$ ft. per second we have a load of 0.2 tons = 448 lb. per lineal inch of effective pinion length (some 80 kg. per centimetre breadth).

It must, of course, be noted that the engagement of double-helical gears follows with no weak points, the mutual contact of the teeth keeping quite uniform all along the line of action; but the lack of sound information as to the load safely transmitted by helical teeth, both with the agreement of formula (1) with long-experienced practice, had the effect of deciding us to establish calculations as aforesaid. We are now observing the behaviour of double helical reduction gears, and hope to arrive at judging the applicability of formula (3) to double helical modern toothed wheels.

Resuming, it seems to us that a film of ordinary lubricant is still effective on the working surfaces of the teeth of cast-iron cut wheels until the maximum specific pressure reckoned as above stated is of the order of 13 kg. per square millimetre. The application of the laws of elasticity to the bearing surfaces of the teeth at the weak points of the path of contact affords a good means of arriving at the relative merit of spur gears for transmitting load without undergoing undue wear.

OTTORINO POMINI, C.E.,
Formerly Lecturer at the Politecnico of Milan,
Technical Director of the Works:
LUIGI POMINI CASTELLANZA, Milan.

CAPITAL AND LABOUR.

TO THE EDITOR OF ENGINEERING.

SIR,—I see in your last week's issue an article with reference to after-war relations between Capital and Labour.

I would put forward what I consider to be a practical solution of the present differences between employers and employed, a solution which, in my opinion, cannot be considered as anything but reasonable to all concerned. My suggestion is that there should be a definite agreement to the following effect :—

The Employers :
Will not reduce the rate of wages ruling.
Will never cut piecework prices except on introducing new methods.

The Employed :
Will not restrict output.
Will not interfere in shop management.

I do not consider that the employers' part of the bargain could be put forward except in exchange for that which the employed are asked to concede. With regard to those employed, I would say that they are asked to give up only something the practice of which cannot be defended on grounds of either justice or equity. Restriction of output is an export tax on manufacture. If the reason put forward for its first introduction was, as has been stated, an apprehension of a reduction in piecework prices, in my solution I have removed the grounds for its continuance, and by so doing have removed all limit to the increased earnings of an efficient workman, whilst not penalising the less efficient.

I have great hopes that the above proposals would be favourably received by both sides and lead to a better understanding all round. With regard to the disputes which must arise from time to time, would not a system of district tribunals as those now in existence meet the case, tribunals in which employers and employed would receive equal justice; these, however, not to be resorted to until every effort has been made by employers and employed to arrive at an amicable settlement?

I remain, Your obedient Servant,
HERBERT J. MARSHALL.

Northolme, Gainsborough, January 11, 1917.

EXPORT PROHIBITIONS.—A supplement to the *Board of Trade Journal*, of the 18th inst., contains complete lists of articles which, according to the latest information received by the Board of Trade, are prohibited to be exported to various destinations from British India, Canada, New Zealand, South Africa, Newfoundland, Egypt, Malta, Cyprus, Mauritius and Ceylon.

TUNGSTEN ORES FROM BRITISH MALAYA.—Some excellent specimens of tungsten ores, wolframite and scheelite, have just been received at the Imperial Institute from the Federated Malay States, and can be seen in the Malay Court of the Exhibition galleries. Wolframite occurs in various parts of the main mountain range in British Malaya, and in Pahang and Trengganu. Scheelite is mined in Perak and Selangor.

UNITED KINGDOM TRADE WITH CANADA AND NEWFOUNDLAND.—It has been arranged for H.M. Trade Commissioner in Canada and Newfoundland (Mr. C. Hamilton Wickes) to pay a further official visit to this country. Mr. Hamilton Wickes, who visited this country in 1915, is expected to arrive early in March, and will be prepared to interview (by appointment) representatives of those firms who may be able to see him in London at the offices of the Department of Commercial Intelligence of the Board of Trade for several weeks before Easter. Immediately after Easter he will visit such trade and industrial centres in the United Kingdom as it may appear most advantageous to visit in view of applications that may be received from firms in or near those centres, and from chambers of commerce. These centres will probably include, in the order named, Bristol and South Wales, Birmingham and District, the Potteries, Manchester, Liverpool, Ireland, Scotland, Newcastle, Yorkshire, Nottingham and Leicester. Firms who may desire to have an interview with Mr. Hamilton Wickes are requested to make their application as soon as possible, and, in any case, not later than February 19 in the case of London, and March 5 in the case of the provinces. Applications should be addressed to the Comptroller-General, Department of Commercial Intelligence, 73, Basinghall-street, London, E.C. The reference number (D.C.I. 2,360/17) should be quoted.

NON-FERROUS METALS.—A paper was read on Monday, December 11, 1916, at the apartments of the Geological Society, Burlington House, by Dr. C. Gilbert Cullis, Professor of Economic Mineralogy in the Imperial College of Science and Technology, on "The Mineral Resources of the British Empire with regard to the Production of the Non-Ferrous Industrial Metals." The particular metals dealt with were: copper, lead, zinc, tin and aluminium. The object was to demonstrate the Imperial position with regard to each of these, and to show in respect of which of them the Empire was, on the one hand, self-sufficing, or, on the other, dependent upon foreign countries. In the latter case, the extent of the dependence was indicated, and methods suggested by which it might be diminished. The situation with regard to four out of the five metals was shown to be wanting in independence and security, and the necessity for a full investigation of the British mine and smelter productions was insisted upon. With regard to copper, not only were the ore resources, as at present exploited, deficient, but the smelting facilities also were seriously inadequate for the Empire's metal requirements. The production both of ores and metal could be substantially increased by suitable organisation and administration. Lead and zinc ores raised in British territory had in the past been exported on a large scale to foreign countries, notably Germany and Belgium, for metal recovery, with the result that the Empire had been placed in an anomalous position of dependence which ought never to have arisen. The shortage of zinc, in the early days of the war, and the consequent jeopardising of supplies of cartridge brass were referred to. The mine production of lead and zinc was more than sufficient for the Empire's requirements, but the smelting facilities were lamentably deficient, especially in the case of zinc. It was urged that all the lead and zinc concentrates of Broken Hill should in future be smelted within the Empire. In the case of aluminium, while the actual bauxite resources of the Empire were so small that dependence had to be placed upon the French or American deposits—which were being more and more utilised in their countries of origin—large potential supplies, in the form of laterite, had a very wide distribution in the tropical colonies, but were almost untouched and untried. The systematic examination of these and other potential sources of aluminium, with a view to their utilisation, was seriously needed. The only metal with regard to which our position was really strong was tin. The British mine production of tin in 1912 was 66,000 metric tons out of a world's total of 125,000, and its smelter-production 85,000. Estimating the consumption at 32,500 tons, there remained 53,000 tons for export. Now that the German market for Bolivian tin ore was closed, an opportunity had arisen of securing the whole of the Bolivian output for British smelting.

WORM GEAR AND WORM GEAR MOUNTING.*

By F. W. LANCHESTER, M.Inst.C.E.

(*Continued from page* 45.)

PART III.

Worm Gear Mounting.

It has frequently been urged, to some extent truly, that the Hindley or Lanchester worm gear requires greater precautions in mounting than is the case with a gear of the parallel type. The point is that whereas in the Lanchester type the worm thrust has to be accurately located, in the parallel type, so long as the worm axis is correct as to position, the longitudinal location of the worm is of no importance. The matter may be carried a step further; worm gear of the parallel type in turn may be said to require more careful mounting than common screw gear, in which both worm and wheel are of the ordinary screw-cut spiral form. Thus the argument that the Hindley or Lanchester gear is at a disadvantage, on account of the extra precautions required, as compared with parallel worm gear, may be quite as reasonably urged against worm gear of every kind in favour of ordinary screw gearing such as commonly used to drive the side shaft of a gas engine. Such arguments are clearly without weight if any adequate advantage can be shown to exist.

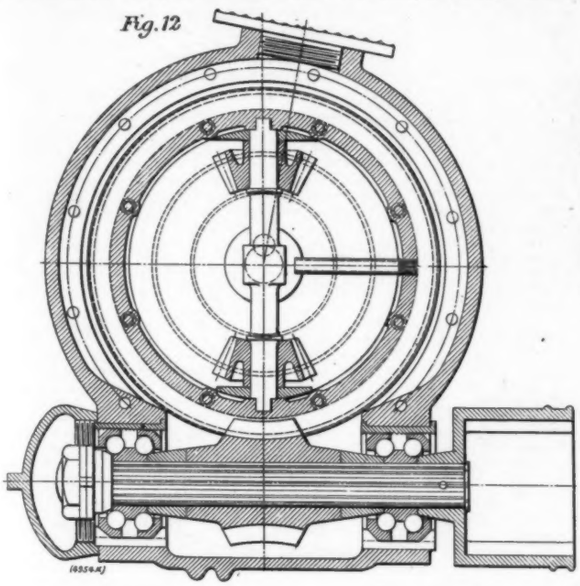
In practice the whole point of difference hinges on the correct location of the worm thrusts, since in every other respect any want or loss of alignment affects both types of gear equally. It may be doubted, as a matter of experience, whether the Hindley type of worm gear is actually at as great a disadvantage as its detractors would represent—the Lanchester gear, at least, has shown itself capable of working surprisingly well under the severe conditions which supervene when a worm thrust bearing fails. Admitting, however, that the durability of the gear does definitely depend upon the permanence of alignment as determined by the thrust bearing, the problem resolves itself into the comparatively simple question of how, under manufacturing conditions, the initial accuracy of alignment can be secured; beyond this, the durability of the alignment resolves itself into a question of fixing the proportion and type of thrust bearing best employed, and of the general soundness of the mounting as a piece of engineering.

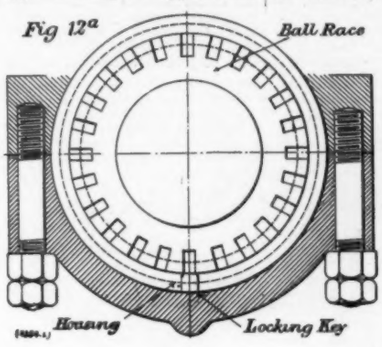
The earliest type of mounting employed in the application of worm gear to the original Lanchester car is shown in Figs. 12 and 13. Here it will be noted that the ball bearings are not of the modern type, the design dating back to a time when such bearings were not a standardised or a marketed commodity; two double bearings of the bicycle cup and cone type are arranged at opposite ends of the worm, the whole combination being symmetrical. The cups were made adjustable by housing them within an internally screwed sleeve piece, and the adjustment was fixed by a key or cotter engaging with one of 24 notches cut in the periphery of each cup, Fig. 12*a*. The pitch of the thread was twelve per inch, so that the design gave a capacity of adjustment to within approximately 3½ one-thousandths of an inch, which was found to give satisfactory results in practice. Here we stumble against one of the misconceptions which are current with regard to the Hindley type of gear: it has often been represented that the accuracy of alignment of the worm requires to be true to within a thousandth of an inch of geometrical accuracy: from the success of the arrangement described, it is clear that no such degree of accuracy is essential.

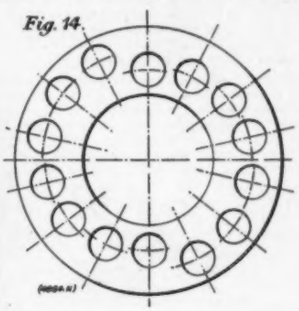
It will be noted in the bearing in question that (as in the case of the old bicycle ball bearing) there is no separate function of cylinder bearing and thrust, and without doubt from a modern standpoint the type of bearing shown in Figs. 12 and 12*a* would be considered lacking in durability. No trouble was experienced from expansion (due to temperature) as between the two thrust bearings, and it is fair to regard the casing, as indeed the whole of the parts, as sufficiently elastic to take up any small temperature difference. It is possible that at times one thrust bearing is called up to to sustain more thrust and at other times less than its fellow, but there has been no actual evidence of this taking place.

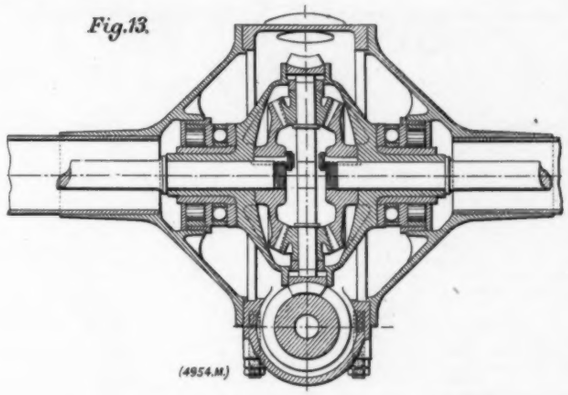
The worm wheel bearings shown in Fig. 13 are roller bearings of the cheese-roller type without cage of any kind. These are in fact the bearings on which the balance gear-box is mounted, and the worm wheel itself forms the central section of the balance gear-box. The thrusts were of a specially designed type, and consisted of balls in a flat cage between two perfectly flat ground and hardened thrust washers, the balls being arranged in a spiral manner,* Fig. 14. The object of this arrangement, *i.e.*, the spiral distribution of the balls, is that each ball may bear on a different part of the flattened surface, so distributing the wear; a further advantage is, that if the balls vary amongst themselves as to diameter, as is commonly the case, each ball will form its own race and will soon be taking its due proportion of the load—the markings on the thrust races frequently gave evidence of this action. The degree of inaccuracy amongst balls of nominally the same diameter is commonly less than one ten-thousandth of an inch. This form of bearing was in every way successful and satisfactory; that it has since been dropped is due to the fact that excellent thrust bearings have now been placed on the market by specialised manufacturers.

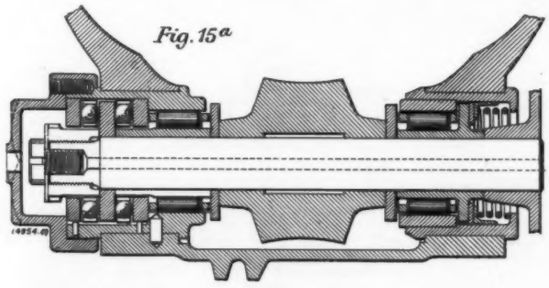
In the modern worm mounting the type of bearing given in Fig. 12 has been long since abandoned, and to-day it is the invariable practice to separate the functions of radial load and thrust and provide for each by a bearing specially designed for the purpose. Thus in Figs. 15*a*, 15*b*, 16 and 19 a roller bearing is employed independent of the thrust, and in Fig. 20 and those which follow it will be seen that the radial bearing commonly used is the symmetrical type of ball bearing

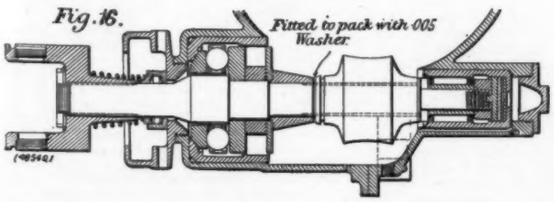


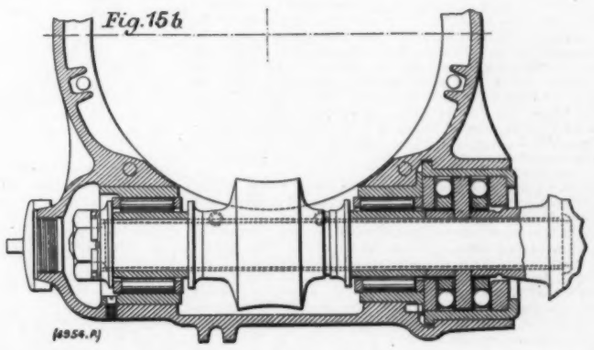












* Paper read before the Institution of Automobile Engineers on December 13, 1916, slightly abbreviated.

* Patent 17,032 of 1901.

as now to be obtained from several firms, such as the Hoffman, Skefko, Duplex, &c., and the thrust is independently carried. In some cases the radial bearing takes the form of a roller bearing, as in the worm wheel bearings already given in Fig. 13.

It is worthy of note that in the modern mountings, the thrust bearing, a double thrust, is almost invariably fitted at one end.* Objection has been taken to this arrangement on the ground that any inequality of expansion between the worm shaft and the casing will throw the worm out of centre, in other words, the objection is based on the fact that the arrangement is unsymmetrical. There are two answers to this. Firstly, the temperature difference is a mere "bagatelle"; thus the whole range of temperatures between the hottest and coolest parts of the gear-box is included between an atmospheric temperature, say, 20 deg. C., and an upper extreme of about 100 deg. C.; speaking generally, the difference between one part and another does not exceed 40 deg. C. or 50 deg. C. At the worst, calculation gives the relative displacement of the worm centre line and the wheel centre line due to the cause stated as not exceeding two or three thousandths of an inch. In practice it is doubtful whether it is ever as great as this: in any case it has not been found to be detrimental. Secondly, if, as is the only alternative, the thrust and counterthrust be arranged at opposite ends of the worm shaft, there will be a much bigger expansion difference to take up between thrust and counterthrust, probably twice as great as that now between worm and thrust bearing. This expansion might have a detrimental effect on the thrust bearings and ultimately lead to their disintegration. The failure of a thrust bearing must be regarded as perhaps the worst "accident" which can happen to a worm gear.

The author will now describe in detail a few of the later and more successful types of worm mounting, and some of those which are historically the more important. The first series which will be taken will be in continuation of Figs. 12 and 15*a b*, showing the historical development of worm mounting in the practice of the Lanchester Company. It will be noted on comparison of the figures given that there are certain features of the Lanchester mounting which have survived from the earliest designs, notably the splined shaft on which the worm assemblage is mounted, also the method of building in the worm wheel as part of the balance gear-box, and in providing for the housing in the worm wheel casting itself of the cross pin or pins on which the balance gear bevels are mounted. In this arrangement, which is common to the whole of the series, is will be seen that the drive from the bevel wheel is taken directly on to the balance pinions, and the covers of the balance gear-box are not used to convey torque but only the thrust and other forces by which the wheel is held in alignment. It will be noted that the thrust bearings serving the balance gear-box take not only the worm thrusts, but also the axle thrusts. There is a bronze pad fitted between the axle ends by which the thrust is coveyed from one axle to the other and thence to the thrust bearing. Another incidental feature which may be noted is the fact that there are four balance pinions in the differential gear-box, each pair mounted on a transverse pin; the figures show clearly the means taken in the design of these cross pins to permit them to clear each other and to clear the axle ends and thrust pad. So far as the worm gear mounting is concerned, these are mere incidents, but the method by which the drive is conveyed from the worm wheel to the balance pinions is a matter which is essentially of interest.

Coming back now to the more directly important points, we may, with reference to Fig. 15*a*, call attention to the first advance in worm mounting after the type shown in Fig. 12. In this we see that roller bearings brought well up to the neck of the worm have been substituted for the bicycle type of bearing in the previous figure, and a double ball thrust between flat parallel races has been applied at the tail end of the worm shaft. This design, again, was before the period in which ball or roller bearings could be purchased from specialised makers, and the bearings were made in every detail at the Lanchester Company's works. It will be seen that the thrust bearing in this design is very compact, but from the modern point of view and with present-day loads and speeds it would not be considered adequate. Owing to the incline of the worm shaft and the importance of ground clearance, the tail position is at a disadvantage compared with the driving end of the worm shaft in the matter of permissible diameter, hence, when we pass to a later design, Fig. 15*b*, in which the bearings (both cylinder and thrust) are far more robust, the thrust is fitted at the neck or forward end. In Fig. 16 (early 20 h.p.) we find that the ball thrust bearing has again been arranged at the forward end of the worm, and in this design an innovation was tried experimentally to do away with the ball counterthrust and employ a series of thrust washers, the efficiency clearly being a matter of no importance when the brake is being employed. A notable feature in this design is the very large diameter of the thrust balls. Fig. 17 gives the corresponding section through the worm wheel axis. Here we see the spiral type of thrust bearing with flat races still holding its own.

A feature which is worthy of mention in many of these early mountings is the employment of the "cheese" type of roller bearing, that is to say, a type in which the length and diameters of the rollers are about equal. This is a type of bearing which the author developed in the experimental period of car building, and which was used in the gold medal phaeton built in 1897–8. The employment of this type of bearing was extended considerably in the 10–12 design in 1900, where it was used throughout the rear axle and parts of the countershaft. It is only within the last few years that bearings of this pattern have been taken up and introduced by the Hoffmann Company and others. There is a difference in practice, inasmuch as the bearings marketed at the present day appear to be all fitted with cages, whereas in the author's experience a cage is absolutely unnecessary in bearings of the "cheese" roller type. In any case the guiding of the rollers is done from the ends, and this is really the definite distinction between the ordinary roller bearing and that of the "cheese" type, in the former the roller being guided from its cylindrical surfaces, the cage being a necessity. Generally speaking, it has been the author's practice so to design the bearing that the rollers, once in position, could not fall out; thus in the axle bearings shown in Fig. 13 the diameters of rollers and races were such that the axle or central race could be removed and the rollers could not be displaced. The clearance was so small that the rollers would lock before they could come free, as illustrated diagrammatically in Fig. 18.

A still later type of mounting is given in Fig. 19. On the worm bearings we again see the cheese roller bearing of the cageless type employed, and a double thrust bearing on the tail end of the shaft. The whole outline of the worm housing, however, has been made very clean and smooth externally. The corresponding axle mounting is given in Fig. 20. Here it may be seen that on the axle bearing the ball has to some extent replaced the roller.

It may almost appear, in looking at these changes, that in some cases, in which the change goes from one arrangement to another, and then back again at a later date, there is certain evidence of infirmity of purpose. As a matter of fact changes are frequently due to conditions which are temporary, and often two designs are so nearly equal in merit that whether one or the other be adopted is purely a matter of convenience. A great deal must depend upon whether the designer has a completely free hand or whether he is required to make use of standard components. It will be noted that amongst the various changes the practice of the Lanchester Company has always been to place the worm shaft below the axle.

One knotty point has existed throughout almost the whole history of gear-box mounting, and that is the manner in which alignment is to be secured. There are four methods open: firstly, the parts may be made with sufficient mechanical exactitude to ensure perfect interchangeability and alignment within the necessary degree of accuracy. Secondly, a screw or other variable adjustment may be provided by which the necessary alignment may be secured in spite of individual variation in the parts. Thirdly, the method of using pen-steel washers or "shims" may be adopted. Fourthly an accommodation piece may be employed.

Fig. 17.

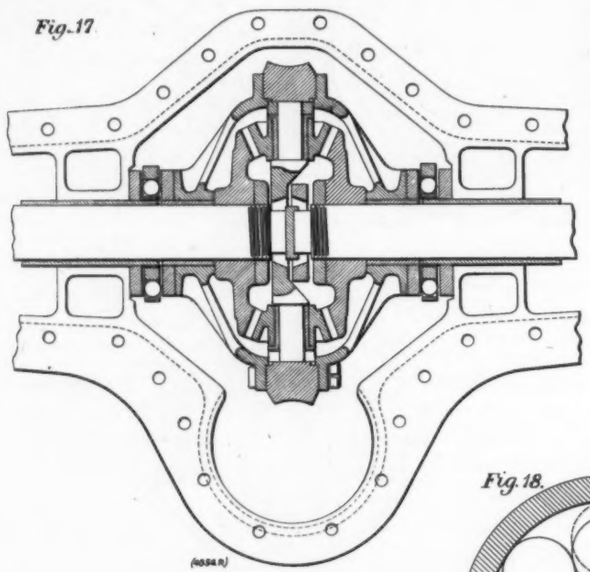


Fig. 19.

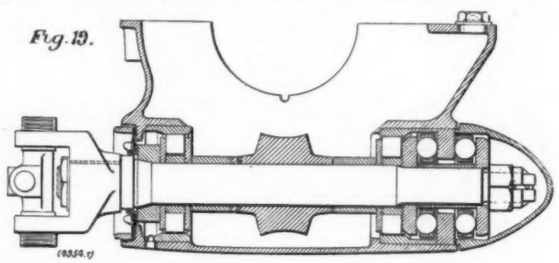


Fig. 18.

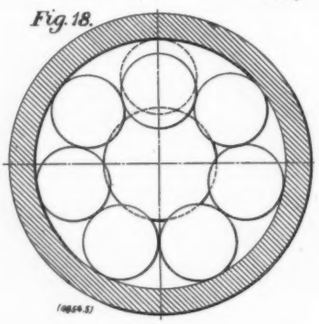
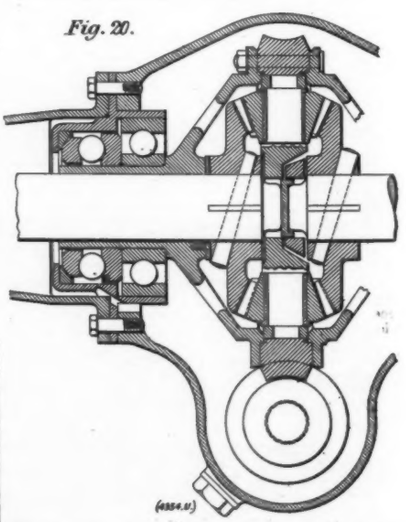


Fig. 20.



In the earliest type of mounting (already discussed Fig. 12) the method of screw adjustment was employed, and up to a certain point was found satisfactory. It had the weakness, however, that, if the mountings were taken down, either the parts would have to be carefully marked, which might be forgotten, or in reassembling an experienced hand would have to be employed—who might not always be available. In brief, the screw-adjusted mounting is not "fool-proof." In departing from this the author endeavoured to attain perfection, and prescribed limits to the components and methods of gauging by which complete interchangeability was secured. This ideal, however, is extremely difficult to get carried out. The number of parts in the "mechanical circuit" is great, and, in order to avoid excessive variation in the aggregate, the individual limits require to be unusually fine. So long as all the components are made in the same works as the car the thing can be done, and it has been successfully done by the Lanchester Company. The difficulty, however, arises when it is desired to increase the output and bearings have to be purchased from firms who specialise in such commodities; the degree of accuracy to which they will guarantee to work

* An exception to the practice of employing separate radial and thrust bearings is to be found in cases where the American type of conical roller bearing has been adopted.

is totally inadequate. In other words, bearing makers will not guarantee to work to thickness limits or width limits less than five one-thousandths of an inch, and if such limits were tolerated the total inaccuracy in the case of a worm mounting would amount to as many hundredths of an inch as it should be thousandths.*

The author has never found it cheaper to work to a low degree of accuracy than to work to a high degree of accuracy. In other words, a thrust bearing can be produced which from face to face does not differ by more than a thousandth just as cheaply as it can be produced to within two or three one-thousandths. Whatever difference of cost there may be is more than compensated for by the advantage of interchangeability. In other words, the actual production of a part accurately to dimensions, that is to say, within fine limits, may be slightly greater, but in any complex piece of machinery the saving in cost of assemblage will pay the bill many times over.

The above is no mere ideal or unsupported opinion, it is based on hard experience. Some years ago, in designing certain mechanism (which need not be specified) every clearance dimension and tolerance dimension was set personally by the author's own hands, and these were worked to for a considerable time with satisfactory results. A new works manager, who did not believe in working to fine limits, reported that the limits were unduly fastidious and that money could be saved by relaxing the limits and so avoiding having to scrap parts. The managing director consented, and the scheme was tried. A slight and questionable reduction resulted in the cost of manufacturing components, but the increased cost of assembling and testing, and the cost of rectifying complaints, &c., became so great that the initial saving was swallowed up many times over. Within twelve months the scheme was abandoned and the old fine tolerances were restored, the expense of twice altering the gauges, &c., being a dead loss apart from the disastrous results of the experiment. The author thinks he could go further and say that he has never made an endeavour to do anything better than previously without finding that when it is being done better it is also being done cheaper. Thus, the "splined shaft" was looked at by some as a piece of fantastic extravagance when first introduced, but it showed itself to be a money saver from the outset; it is far cheaper to cut a splined shaft and drift the hole to correspond, than it is to cut a keyway and make and fit a key; also the job is incomparably better engineering when done. It is perhaps the more legitimate to cite this example, since it was in connection with worm mountings that the splined shaft was first introduced into motor car practice; the worm shaft of the 10-12 h.p. Lanchester car, Fig. 16, also the gear-box, were, the author believes, the first applications of the splined shaft in the history of automobile engineering.†

Returning to the main point under discussion, it has been stated that though commercially possible, and probably advantageous, to fix the limits of the various components to secure perfect interchangeability in a worm gear mounting, it can only be done provided that the whole of the parts are made by the builders; at least in cases such as ball or roller bearings the offending dimensions must be rectified after they have been received from the manufacturer. There are commonly some eight parts or thereabouts of which the tolerance differences accumulate, and to attain perfect interchangeability the whole sum of these‡ must be kept down to within four or five one-thousandths of an inch. Admittedly the individual limits are fine. Owing to the difficulty of obtaining the necessary interchangeability, especially where ball bearings, &c., were ordered from outside sources, the Lanchester Company have from time to time resorted to an accommodation piece, or have made use of "shims" in order to secure the necessary accuracy of alignment. There is more to be said in the case of a worm gear mounting for this practice than might appear to the idealist; it is, for example, admitted that the various components, thrust bearings, &c., are liable to a certain amount of wear; occasionally, also, the whole assemblage will be found to have developed internal sloggar, in which case the components may undergo considerable "punishment" and additional inaccuracy is introduced. Under these conditions the use of shims in the repair shop is fully justified, and a very good job indeed can be made if the points at which the shims are inserted are such as to present a sufficient area, and if the shims themselves are of pen steel or other suitable hard grade of material. If this be not the case, there is always the danger of the shims being spun out or hammered out, and eventually disintegrating, in which case the parts may get loose in the gear-box.

There is also the fourth expedient above given: the accommodation piece. In all interchangeable work in mechanical engineering a point may ultimately be reached when the accumulation of the tolerances of the individual components results in the individual limits having to be cut down to a point below anything which may be considered reasonable. It then becomes a question of judgment for the designer (as in the case of the worm gear under discussion) how the difficulty is to be met: one method is that of the accommodation piece. Thus one piece in the whole "mechanical circuit" is left to be fitted, or is made in several different standards of thickness. This is far better practice than to have a pretended interchangeability which does not really exist in which the accumulated tolerances do not come within the aggregate limit, and which in the assembling of a machine has to depend upon the selection of compatible components. Thus on many pieces of mechanism at present being manufactured for the Government there are limits specified on the aggregate assemblages which are inconsistent with the limits permitted on the individual components, so that a manufacturer may make his components within the limits specified and yet he may not have a single assemblage which will go together. It is frequently true that it would be far easier to put finer limits on the individual components and devise means of working to them, but obviously, as already stated, there is a limit to what is commercially possible. When this limit is reached the alternative to the very unsatisfactory state of things above described is to make one of the components an accommodation piece, and either admit that part as a fitter's job, that is to say, allow it to be filed or otherwise adapted to the rest of the assemblage, or else to make that particular part in sufficient variety and confine the selecting to that one particular component.

In the Appendix is given an example of a case where the number of dimensions in the mechanical circuit is about normal for a worm transmission, and examples of suitable component dimensions are given in detail as figured on an interchangeable basis. In the worst or extreme cases given by these dimensions the difference amounts to 0.01 in. in the worm and wheel location; this may be taken as within the limits of good practice. It is clear from this example that a very high degree of accuracy in manufacture is necessary in order to obtain the desired result.

The difficulty mentioned in the case of "shims," namely, that they are liable to be spun or beaten out, is a difficulty met with more broadly and in a more general way in worm gear mountings. The parts intervening between the thrust and the worm appear in practice to need to be able to stand a lot of "punishment," and it is most important that no backlash shall exist. The consolidation of the worm shaft assemblage is usually provided for by pulling the whole string of components, namely, worm, distance piece, bearing ring, thrust washer, &c., thoroughly solid by a nut of ample proportions, as may be seen from the various figures. In some cases this nut has been locked by means of a caulking plate, in other cases the customary split cotter has been employed. Where the latter practice is adopted it is important that the nut shall be pulled thoroughly home before the hole is drilled for the split cotter, and even under these conditions there are certain objections to locking in this way. Owing to the trouble which has been found to develop if any initial backlash once makes its appearance, it has been the author's practice for some time to specify that all the components forming this compression assemblage shall be hardened, either being made of a high-carbon steel or case-hardened, according to circumstances. When this precaution is taken, and when the abutting areas are made sufficient, all trouble from the case stated has been found to cease.

(To be continued.)

* The Hoffmann limit of the width in a standard ball-bearing is ± 0.055, a total variation of 0.010 or ¼ mm.

† In Figs. 15a, 15b, 16, 19, &c., splined shafts are employed in every case, but the splines are not shown in detail.

‡ Compare Appendix.

IRON IN GERMANY.

THE change of the year is likely materially to alter the aspect of the German iron market. After negotiations, extending over more than six months, between leading representatives of the iron industry and the Government authorities, the latter have at last sanctioned the rise in prices for which the former held out, with exception of the Steel Union, for which no increase in quotations will take place for the first quarter of the new year. Whilst the rise in the prices of coal and coke was fixed on what may be called a medium basis, the increase in ore containing manganese has been on a more lavish scale, amounting to no less than 7 marks per ton. Dearer fuel and dearer ore naturally lead to higher prices for iron products, and for some sorts of pig an advance of 25 marks per ton has been decided upon, even if the rise has not yet been actually announced. German foundry pig No. 1 has been raised 25 marks per ton, and is now quoted at 121 marks per ton for the selling district No. 1; German foundry pig No. 3 now costs 116 marks per ton. Hematite has also been put up 25 marks, and is now quoted at 167.50 marks per ton, the price being put up 20 marks in September, 1916, which fact served to prevent an even greater increase on the present occasion. For Luxemburg foundry pig the advance amounts to 13 marks per ton, making the present price 89 marks. Other kinds of pig-iron have been raised in accordance with the advances just referred to.

The prices for iron ore of the different types, after the last increase, range from 23 marks to 25 marks per ton for raw ore. The Minette ore has also risen. The Siegerland iron ore is disposed of through the selling bureau; of the ore from the Nassau district but small quantities remain free for the whole of the current year, greatly owing to the continued acquirement by iron works of the mines in question, which, of course, reduces the quantity available for the open market.

As regards scrap, the upward movement has come to a stop, after a rise of some 100 per cent. on the year, arising from the extremely active demand for scrap by the Martin works, which, on account of the scarcity of pig, used scrap on an increased scale. Several scrap-iron depôts have been formed under war industrial organisations, where prices are fixed and the distribution arranged. This method will also help to frustrate the excessive speculation in this commodity.

Although the quotations for ordinary commercial iron products are in the meantime to remain unaltered, the rise in the price of the raw materials is likely to influence the quotations for quality goods, and for such an advance may no doubt, be looked for in the immediate future. Such large orders have, however, been accepted by the works in question for the next few months, that only very limited quantities are likely to come on the market.

A report from the south-western district states that the position within the iron industry, including the Luxemburg works, continues favourable, as it has been through the whole of 1916. During the last few weeks the shortage of labour has been alleviated, but, on the other hand, the insufficiency of rolling-stock causes considerable trouble, both in the matter of the supply of coal and the despatch of the finished products, a state of affairs which again emphasizes the necessity of the Saar-Moselle Canal scheme being realised. Hopes are expressed that this work will be undertaken as soon as the war has come to an end. The demand for pig-iron continues exceedingly active, the entire production is promptly snapped up, and far larger quantities could be readily disposed of. The demand for direct and indirect war requirements is immense, and all stocks are apparently cleared; and although all building for other than military purposes is at a standstill, the demand for No. 1 and No. 2 girders exceeds the supply. The works are stated to have specifications waiting to be delivered for months to come. The same applies to half-finished and bundled goods. Of railway material, both light and heavy, only the most urgent quantities are being rolled.

The bar-iron market has for several months presented a somewhat peculiar aspect. The fixed prices continue at 190 marks per ton, on the freight basis Diedenhafen, and 195 marks per ton at Oberhausen, net cash. At these prices, however, it has been impossible to obtain anything, either first or second hand. The prices are official, the sale is free, but there is nothing to sell; in almost all districts the production is out-sold for months to come, the works being taxed to their utmost capacity. Added to this come the regular monthly requirements of the military authorities. Stocks, even antiquated, have been almost completely exhausted at the works; the same may be said to apply to the trade. For available stocks fancy prices are often asked and paid. A perfect run on the works for the renewal of stocks is anticipated after the end of the war.

The market for plates shows a similar condition. All kinds and conditions of plates—heavy, medium, fine and corrugated, tinned, galvanised, &c.—are cleared out, and prices are paid as have not been known for decades. The direct and indirect war industries require large quantities, which the manufacturers have difficulty in supplying, suffering as they do from want of raw material. Thin plates, especially, are in active demand, and galvanised plates No. 24 are dearer than zinc plates.

As the production of gas pipes has been almost discontinued for several months, prices have tightened, and the same applies to fittings. As regards bright and galvanised wire, barbed wire, wire netting and wire nails, the production can hardly keep pace with the demand; the stocks of these articles have also been almost entirely exhausted. Prices continue to rise and have already reached a fairly high level.

Construction works, wagon makers, locomotive manufacturers and iron foundries continue well employed. Machine manufacturers, especially makers of lathes and other machine tools, cannot nearly keep up their production on a level with the demand.

LIFE-SAVING IN MINES.—The first International Congress for Safety and the Prevention of Accidents in Mines, held in Vienna in 1908, resolved that all cases of accidents should be recorded in detail. There was little agreement as to methods of classification, however, and some of the records collected in different mines were of questionable value. A second congress, held in 1913, went further into the matter, and it was thought best to deal with the year 1913 still on the actual system in use, and to begin new statistics with January, 1914. The statistics for the years 1905 to 1915, published by the "Zeitschrift für Berg-, Hütten- und Salinenwesen in Preussen, 1916," pages 71 to 107, are more interesting perhaps in their details than in their summaries. The number of apparatus (portable breathing apparatus, supply of oxygen by hose, life-restoring appliances, &c.) had much increased in Prussia after the great accident in the Reden Colliery in 1907; but the time has hardly come yet to pronounce finally on the merits of the one or other type of appliance. The "gas-diving apparatus," *i.e.*, appliances which enable men to work in poison-gas atmosphere, in use in the mines numbered 2,794 in 1913 and 3,070 in 1914; those of the Dräger and Westphalia type predominated, the old Shamrock (colliery) type was disappearing. The chief life-restoring apparatus were the Dräger pulmotor, the Brah apparatus, and the appliances of the Inhabad Gesellschaft, of Charlottenburg, which mechanically restore and assist breathing. There seems to be no case in which a man apparently killed by electric shock was revived; in such cases oxygen has to be reintroduced into the blood and the heart's action to be re-stimulated, and the rescue attempts appear to have been started too late or not continued long enough. Combined breathing and revival apparatus saved life in 59 out of 191 cases. The apparatus were mostly in proper condition when used; but there were failures—a few fatal—because the potash store was exhausted, or because the apparatus leaked, or was not properly manipulated. This latter point, want of experience in working the apparatus even by the members of the specially trained staff, seems to be an important factor, though in some districts, at any rate, authorities, masters and men certainly co-operate in a praiseworthy manner. During the year 1915, 19 out of 46 victims were revived.

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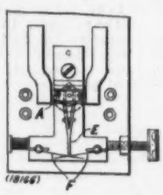
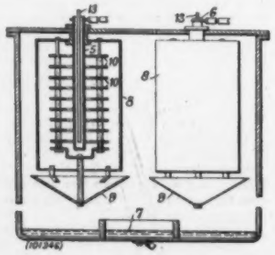
ELECTRICAL APPARATUS.

18,166/15. S. G. Brown, North Acton. Electrical Relays. (3 *Figs.*) December 30, 1915.—This invention relates to electrical relays employing a coil-operated moving member adapted to meet a sloping contact surface. According to this invention, the local circuit is provided with a stationary contact member placed across the path of the coil-operated moving member at a comparatively small angle to the said path and so arranged that the moving member is stopped by a wedging action on the slanting contact surface. The moving member has therefore no tendency to rebound (as is the case when it moves directly against an abutting surface) owing to the fact that the contact has a sliding component. At the same time there is no such gripping action as would prevent the easy release of the



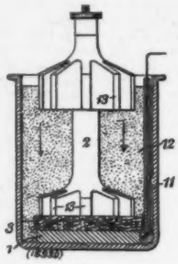
moving member on reversing the current. In a convenient construction of relay embodying the invention, the local circuit contacts comprise two members F, F set at a small angle to each other, a contact arm E carried by the receiving coil A moving between the angular members so as, when swung to either side, to make contact with one or other of the said members by a slanting blow. A slight amount of resiliency in one or both of the relay elements may be desirable to give the most efficient contact, such resiliency, owing to the slanting nature of the contact, giving no tendency to rebound. The moving arm may consist of a small wire having its end bent down to form a spring tip meeting either one of two fixed wires in the local circuit, which may cross each other at the desired angle, without, of course, actually touching. (*Accepted November* 22, 1916.)

101,346. The British Westinghouse Electric and Manufacturing Company, Limited, London. Vapour Electric Converters. (3 *Figs.*) August 28, 1915.—This invention relates to shielding systems for vapour electric converters and consists of the combination with an elongated anode of a shield therefor comprising a plurality of conducting rings mounted co-axially therewith and a baffle member across the end of said anode. The container is provided with a pair of anodes 6, and with a cathode 7. The anodes 6 and the cathode 7 are connected in a rectifier circuit of any usual form (not shown). The anodes 6 are preferably formed by boring out a piece of hot-rolled steel shafting, and are provided with cooling tubes 13 for the circulation of fluid therethrough. The anodes 6 are further provided with shielding members, each of which comprises



an insulated cylindrical conducting casing 8 which is open at its lower end. A deflecting cone 9 of heat-resistant material is supported below each of the members 8 and is spaced therefrom to permit the entrance of a rectifying arc. A plurality of conducting rings 10, 10, are mounted co-axially with the anode and are supported from the top of the member 8. The operation of the improved device is as follows:—The power arc between the cathode 7 and one of the anodes enters between the members 8 and 9 and passes up into the annular space between the member 8 and the rings 10. It is here divided into a plurality of portions by the action of the rings 10, and impinges upon corresponding zones of the anode, thus insuring uniform distribution of the arc over the anode under various conditions of load. (*Accepted November* 22, 1916.)

15,930/15. C. Fery, Paris, France. Electric Cells. (6 *Figs.*) November 11, 1915.—This invention relates to electric cells having negative zinc and positive carbon electrodes, of the kind in which the zinc electrode is situated only at the bottom of the carbon electrode, and depolarisation is effected only at the upper part of the carbon electrode. 1 is the zinc electrode placed at the bottom of an insulating vessel 11 of glass, and covered with a sheet of felt 3 which separates it from the bottom of the positive carbon electrode 2, the whole cell being filled with pumice powder 12 or any other inert absorbent material, wetted with a solution of sal ammoniac. The upper and the lower parts of the carbon electrode are provided with wings 13, so that its median portion is of smaller section than the end portions. This form of electrode also gives excellent results when employed in free liquid cells. It has the advantage of increasing the section of the liquid traversed by the depolarising currents, the direction of



which is that shown by the arrows. Moreover, it occupies less space than an electrode of uniform section, thereby permitting of increasing the volume of the exciting liquid. (*Accepted November* 22, 1916.)

GAS-ENGINES, PRODUCERS, HOLDERS, &c.

102,121. Albion Motor Car Company, Limited, and T. B. Murray, Scotstoun. Internal Combustion Engines. (2 *Figs.*) July 9, 1916.—According to the invention, the governor is arranged on the idle end of the crankshaft B and within the crank-casing H. Its muff E is connected by a lever or link F with a longitudinal member K, endwise movable, arranged within the crankcase and extending to a position immediately beneath the usual induction pipe S. A vertical member Q, arranged within a hollow pillar T extending between the crankcase top and the induction pipe, is operatively connected to the longi-

Fig. 1.

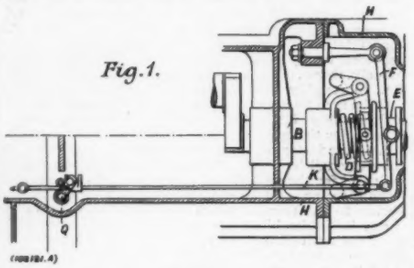
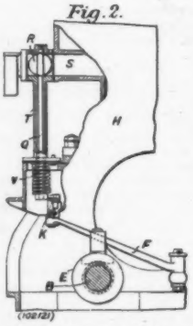
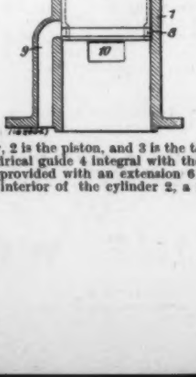


Fig. 2.



tudinal member and operates a throttle valve, preferably of butterfly form, in the induction pipe. A spring V, acting upon the throttle valve to tend to shut it, is provided, this spring being of lesser intensity than the usual governor spring D, so that until centrifugal action takes place in the latter the throttle valve remains open. A certain amount of idle movement is provided in the connections, so that should the movement of the governor due to excessive engine speed be excessive the throttle valve shall not be strained or damaged. (*Accepted November* 22, 1916.)

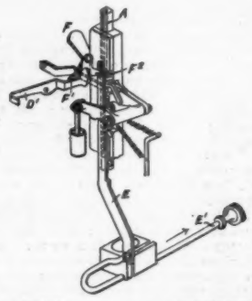
102,006. J. F. Knight and R. P. Doudney, London. Internal Combustion Engines. (4 *Figs.*) March 8, 1916.—The invention relates to valveless two-stroke cycle engines.



1 is the cylinder, 2 is the piston, and 3 is the tail rod adapted to work in a cylindrical guide 4 integral with the cylinder head 5. The guide 4 is provided with an extension 6 projecting downwards into the interior of the cylinder 2, a series of exhaust ports 7 being arranged in the extension 6 just beneath the cylinder head 5. The piston and its tail rod are hollow, the interior of the rod opening into the piston. The tail rod 3 and the piston 2 are provided with packing rings 8. The crank end of the piston 2 is open to the crank chamber; 9 indicates the inlet port leading from the crank chamber; 10 indicates the intake from the carburettor. The operation is as follows: During the forward stroke of the piston the fresh charge which has entered the crank chamber through the intake 10 is compressed by the piston while freely circulating through the interiors of the piston and tail rod. When the piston opens the inlet port 9 the upper end of the tail rod opens the exhaust ports 7 in the extension 6 of the guide 4, with the result that the incoming compressed charge expels the burnt gases in the interior of the cylinder, which can pass freely through the exhaust ports 7 out through the interior of the guide 4 above the closed end of the tail rod. The complete exhaustion of the burnt gases in the cylinder is helped by the vacuum created in the interior of the guide 4 during the forward movement of the tail rod and also by the partial vacuum caused by the exhaust opening slightly before the inlet. Owing to the position of the packing rings 8 there is no leakage during the compression stroke of the piston. (*Accepted November* 15, 1916.)

PRINTING AND ALLIED MACHINERY.

15,630/15. Lanston Monotype Corporation, Limited, London (*Lanston Monotype Machine Company, Philadelphia, U.S.A.*). **Typographical Machines.** (4 *Figs.*) November 5, 1915.—The invention relates to typographical machines furnished with justification space-registering mechanism. According to this invention, there is combined with a shift mechanism-controlling lever, a space-counting bar A and a hand-operated bar E, a coupling member mounted on a shift valve-controlling lever D^1 and arranged to be acted upon by the bars E and A to move the lever D^1, and also capable of being moved relatively to the lever D^1



to release the bar A. One arm F^1 of the lever F normally rests on the top of the lever D^1. A second arm F^2 passes through a notch formed in the upper end of the bar E and projects into the path of the shoulder on the bar A. When the predetermined number of justifying spaces has been inserted in the line, the shoulder on the bar A engages the nose of the arm F^2, and the continued upward movement of the bar A carries the lever F with it and also the lever D^1 to operate the shift valve, since the arm F^1 resting on the lever D^1 prevents the lever F from turning on its pivot. Similarly, should the operator move the rod E^1, the bar E is lifted, and in rising engages the lever F to raise it and turn the lever D^1 upon its pivot. (*Accepted November* 8, 1916.)

102,005. Linotype and Machinery, Limited, London. (*Mergenthaler Setzmaschinen-Fabrik, G.M.B.H., Berlin, Germany.*) **Linotype Machines.** (3 *Figs.*) March 6, 1916.—This invention relates to linotype machines, particularly those which are provided with several magazines, and in which are used matrices having font-distinguishing notches in their feet. The frame 1 of the separator carries the font-distinguishing bridges, as well as the distributor screws, the lower mutilated screw 2 being arranged in bearings, which are pivotally connected to the frame 1. One screw of the font separator is driven by a shaft 5 which is geared with the other screws by pinions 6. The shaft 5 has a clutch ring 7 axially movable but angularly fast on it, with which ring a lever 8 engages. The lever 8 is connected by a rod 9 with a lever 10 which rocks about a fixed pivot and has a cam surface 12 (Fig. 2) abutting against a stop 13 fast to the adjacent bearing of the screw 2. The shaft 5 is

Fig. 1.

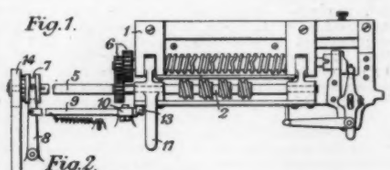
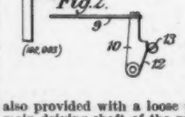


Fig. 2.



also provided with a loose pulley 14 which is driven from the main driving shaft of the machine by a belt and which can be coupled and uncoupled from the shaft 5 by the clutch ring 7. When the screw 2 is in the operative position, as shown, the stop 13 bears against the lever 10 and holds it in its leftmost position, thereby, through the rod 9 and lever 8, maintaining the clutch ring 7 in engagement with the pulley 14, against the action of a spring constantly tending to throw the clutch out, so that the shaft 5 is driven and the separator operates in the known manner. When, however, the screw 2 is rocked, by means of the handle 17, into the position in which the interior of the font separator is open to inspection, the stop 13 is moved out of contact with the lever 10, thus permitting the spring acting through the rod 9 and lever 8 to disconnect the clutch 7 from the pulley 14, whereby the separator is stopped. On the return of the screw 2 to its operative position the stop 13 glides over the cam surface 12 of the lever 10 and restores that lever to its leftmost position, throwing in the clutch and causing the normal operation of the separator to be resumed. (*Accepted November* 15, 1916.)